SECTION 13
TIMBER STRUCTURE

13.1 INTRODUCTION TO RATING TIMBER BRIDGES RATINGS

This section covers the rating of timber stringers and decks. All timber members will be rated using the policies and guidelines in Section 1.

All timber stringers shall be rated using the AASHTOWare Bridge Rating program BrR. The timber decks shall be rated with CDOT Timber Bridge Rating program that is available from the Staff Bridge Branch Software Library.

All other types of timber stringers and decks will be rated in compliance with the applicable guidelines within this manual and the AASHTO codes.

Examples are presented for the three-stringer types listed below, as well as transverse nail laminated timber decks, and transverse plank timber decks.

Timber structures are repaired with the sister beam method using guidelines in Subsection 13.8.

For rating non-timber decks, see Section 3.

An important aspect of rating timber bridges is that the rating should reflect the actual condition of the members, as reported from field inspections. The guidelines for evaluating and accounting for the condition of timber members are shown in Subsection 13-3.

The types of stringers covered by this section are:

TS - Timber Stringer - Timber Deck
TTD - Treated Timber Stringer - Concrete Deck
TTS - Treated Timber Stringer - Timber Deck

13.2 POLICIES AND GUIDELINES FOR RATING TIMBER STRINGERS

13.2.1 General

A) Allowable stress method shall be used to rate timber structures.
B) Timber stringers shall be rated using the BrR program. Nail laminated and plank decks shall be rated using the TIMBER computer program as mentioned in Subsection 13.6.
C) When plans are not available, timber stringers may be rated with BrR software using field dimension in accordance Section 1.7.1.

D) When plans are not available, the allowable stress values in Section 1.5 Table 1-3 for Douglas Fir-Larch Select Structural can be used.

E) The allowable stress value for shear may be increased by a modification factor of 1.33. This factor will always be used for stringers without splits and in good condition. If a beam or stringer is split horizontally, the increase factor is not allowed; see Subsection 13.3.

F) Adjustment factors for timber deck and stringer may be defaulted by using the BrR compute button.

G) For structures constructed after year 1960, the allowable stresses shall be modified according to the AASHTO STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES.

H) For existing timber bridges, CDOT used lumber that has not been dressed / surfaced. The stringers may be considered as the full-sawn lumber sizes. The stringer sizes as presented in the design plans, or CARDEX may be used for ratings rather than dry dimensions, except the actual dimensions are verified by the inspectors.
Commentary: The full-sawn lumber is the same size as the stated nominal size. (Timber Bridges Design, page 3-40, Construction, Inspection, and Maintenance, 1990 – Michael A. Ritter, United States Department of Agriculture, Forest Service).

I) The rater shall evaluate and account for the condition of timber members as specified in Subsection 13.3.

13.2.2 Stringers Requiring Rating

A) Interior Stringers - A rating is required for the critically loaded interior stringer combined with the worst condition. Factors that influence condition are splits, broken, and repaired stringers, and wood condition. More than one interior stringer may require an analysis due to variation in span length, stringer size, stringer spacing, differences in loads or moments, etc.

B) Exterior Stringers - An exterior stringer shall be rated when the section used is different than the section used for an interior stringer.

13.2.3 Dead Loads

A) When rating timber bridges with timber decks use the maximum asphalt thickness obtained along a transverse cross section taken at midspan, rather than the average thickness, for dead load calculations.

B) For timber or metal plank decks, dead loads due to railing curbs, and wheel guards shall not be distributed to all stringers, but shall be considered to be carried by the exterior stringer.

C) The method of applying dead loads due to utilities is left to the rater's discretion.

13.2.4 Rating Reporting / Package Requirements

The rater and checker shall complete the rating documentation as described in Section 1 of this manual. Any variation from the original design assumptions shall be added to the Rating Summary Sheet as applicable. The rating package requirements shall be per Section 1.13 of this manual and as amended herein:

Consultant designed projects – Before finalizing the rating package and when BrR is used as the analysis tool, the Rater shall verify with the Staff Bridge Rating Coordinator that the version number of the program being used is identical to CDOT'S version number. Data files created using a lower, or higher version of the program shall be rejected, except if approved in advance by the Bridge Rating Engineer. It is required for the CDOT data archive, since the data base management feature inside the program would not work satisfactorily. After the analysis is completed, the rater shall save the data file. When saving is finalized, the rater shall export the data file in *.xml format (i.e., O-18-BY.xml format).

13.3 EVALUATING CONDITION OF TIMBER MEMBERS

13.3.1 Broken Stringers

A) In a broken stringer the wood is completely separated. The separation must extend a distance equal to or greater than one-fourth the depth of the stringer.

B) For a broken stringer, the rater shall assume that the stringer is not there. Use stringer spacing equal to 1.5 times the actual spacing for dead load and live load distribution calculations.

13.3.2 Cracked Stringers

A) A cracked stringer is similar to a broken stringer. A cracked stringer must be separated completely through the stringer in a lateral or transverse direction (at or nearly at 90 degrees to the longitudinal axis of the stringer); however, the separation must not extend vertically into the stringer more than one-fourth the depth of the stringer.

B) The rater will evaluate the crack as follows, depending upon its location in the stringer:
1. In the 1/4 span closest to the support the rater shall use the allowable shear stress values given in AASHTO without the shear increase factor from subsection 13.2.
2. In the center-half of the span, the rater shall calculate the effective or reduced section depth, corresponding to the crack location on the beam, in order for the TIMBER computer program to determine the bending moment capacity.

13.3.3 Split Stringers

A) To be a split, it must penetrate completely through the stringer and may or may not extend the full length of the stringer.

B) A split will not reduce a member's bending capacity.

C) For stringers that are split the allowable shear stress values given in AASHTO shall be used without the shear increase factor from Subsection 13-2.

13.3.4 Checked Stringers

A) A check is a separation of the wood along the fiber direction resulting from stresses set up in wood during seasoning, and usually extends across the rings of annual growth.

B) Checks in a stringer may be on either or both sides.

C) A check will not be considered to reduce the load carrying capacity of a timber member.

13.3.5 Shaked Stringers

A) A shake is the result of the growth in the tree and may easily be mistaken as a check.

B) A shake will not be considered to reduce the load carrying capacity of a timber member.

13.3.6 Decay

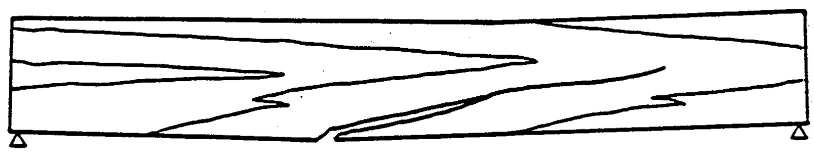
A) Decay can reduce a member's load capacity.

B) A reduced section will be rated for shear or bending strength depending on the location.

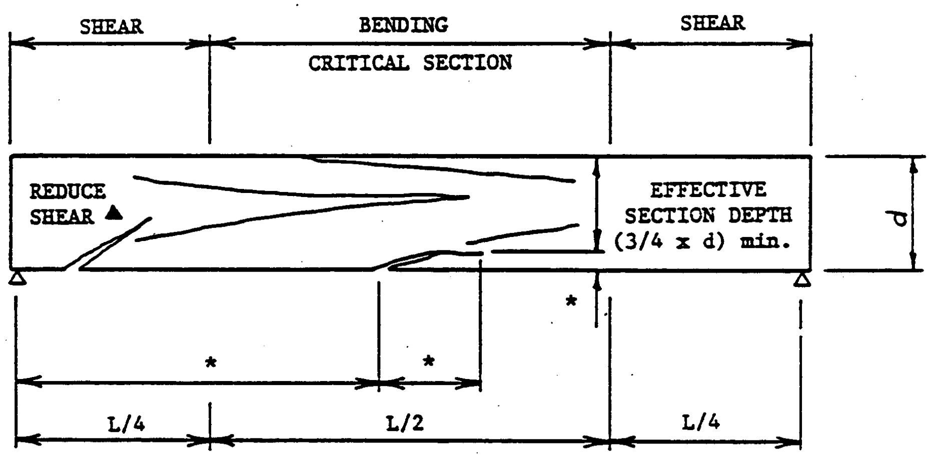
13.3.7 Aging

A) No adjustment in the allowable stresses for timber is necessary for reasons of aging alone. This is in accordance with ASTM D 245, April 10, 2000.

EVALUATING CONDITION OF TIMBER MEMBERS

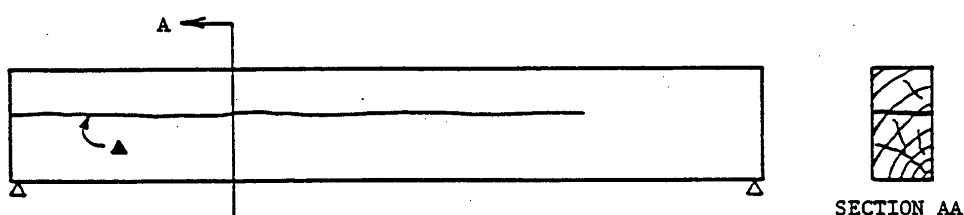


BROKEN STRINGER



* REQUIRES DIMENSION

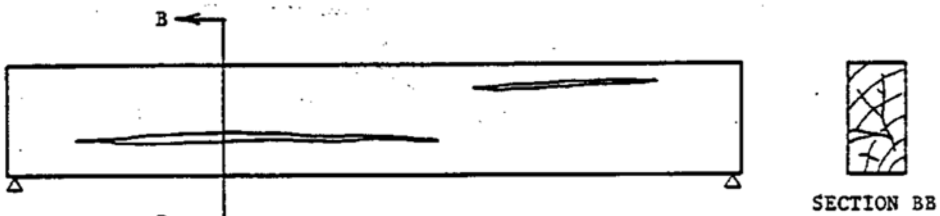
CRACKED STRINGER



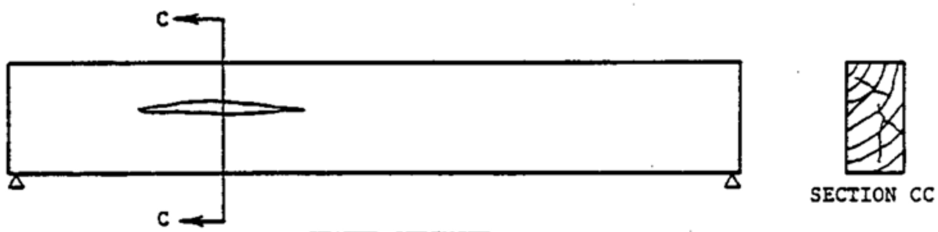
SPLIT STRINGER

▲ Use allowable shear value (F_v) without 1.33 increase in these areas.

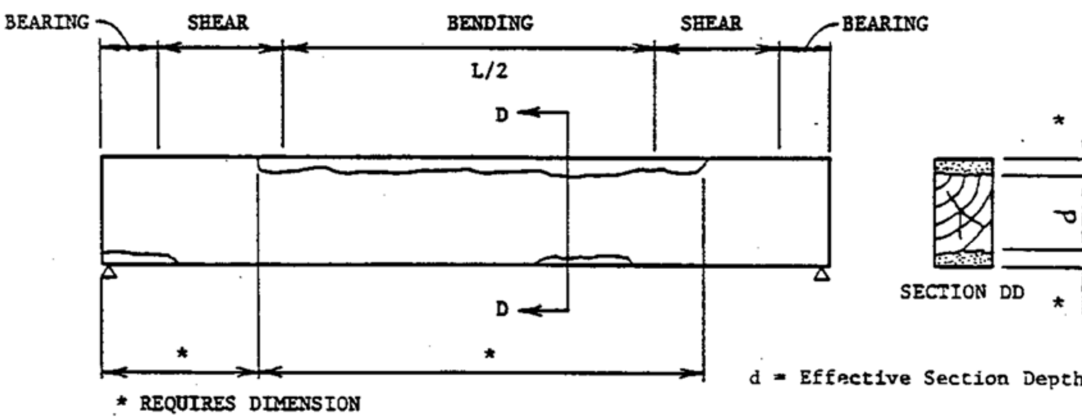
EVALUATING CONDITION OF TIMBER MEMBERS



CHECKED STRINGER



SHAKED STRINGER



DECAYED STRINGER

13.4 GUIDELINES FOR USING THE BrR RATING PROGRAM

The BrR computer program performs the analysis and rating of simple span timber bridges. BrR uses the Madero ASD analysis engine. This program was developed in accordance with the AASHTO STANDARD SPECIFICATIONS and the AASHTO MANUAL FOR CONDITION EVALUATION OF BRIDGES.

The program will not rate sawn timber decks, glue laminated stringers, glue laminated flooring, flooring placed longitudinally, splined or doweled flooring, multiple layered decks, nor nontimber decks. For required modification to the allowable stresses, see Subsection 13.2 and 13.3.

The library explorer can be used to save commonly used items (beam shapes, non standard vehicles, materials, appurtenances etc.) and this eliminates the need for all users to define the same items repeatedly throughout the program. Once a new girder shape is defined or copied from the library, BrR automatically computes the required section properties and beam constants.

The program does consider uniform dead loads other than those caused by the stringers, deck, and overlay. In the case where other dead loads are present that would substantially affect the rating, they shall be accounted for during the analysis.

In the Live Load Distribution Factor window, when the compute button is used to calculate the DF's automatically by the program, BrR users shall verify that these numbers are accurate and matches their calculated numbers.

Timber structures should rate using ASD for three stringer conditions (**no split stringer, split stringer, and repaired split stringer**) based on updated section 1 in CDOT BRM, as shown below:

A) For no split stringer (more than 75% of the total number of stringers have NO splits or shear cracks) should use inventory bending stress 1600 psi and 113 psi for inventory parallel shear stress.

B) For split stringers (more than 25% of the total number of the stringers are not repaired or have shear cracks) should use inventory bending stress 1600 psi and inventory parallel shear stress 85.0 psi.

C) For repaired split stringer by lag bolts (more than 25% of the total number of stringers are repaired) should use inventory bending stress 1600 psi and 98 psi for inventory parallel shear stress.

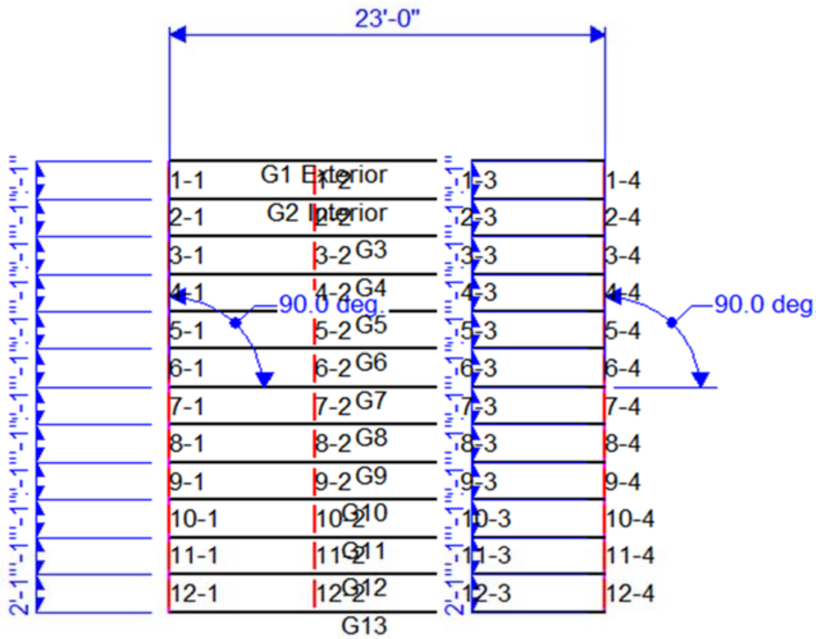
In rating summary sheet rater should report all interior stringer capacity for three above condition, with referring for current stringer condition split/no split or repaired.

One example is presented for structure A-27-A, a two span bridge having treated timber stringers with timber decks. For simplicity, only one span has been modeled using the above conditions of the members as reported in the field inspection report.

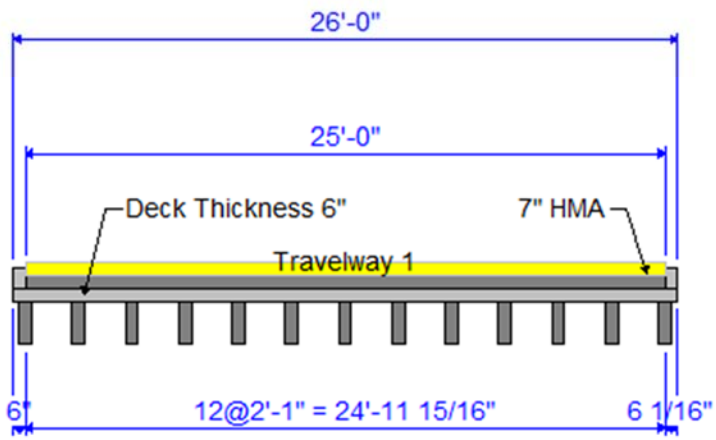
13.5 BRIDGE RATING EXAMPLE

TIMBER STRUCTURE EXAMPLE, STRUCTURE NO. A-27-A

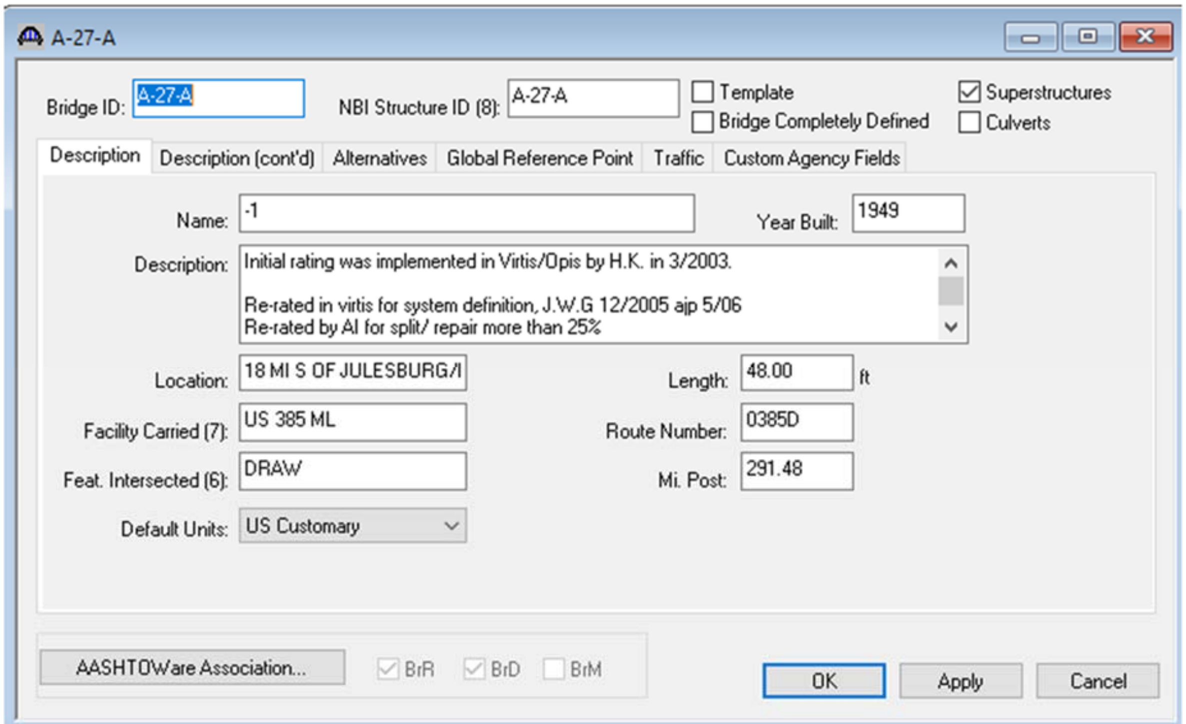
A-27-A
-1 - No split Structure Definition # 1
US 385 ML / DRAW
06/24/19



A-27-A
-1 - No split Structure Definition # 1
US 385 ML / DRAW
06/24/19

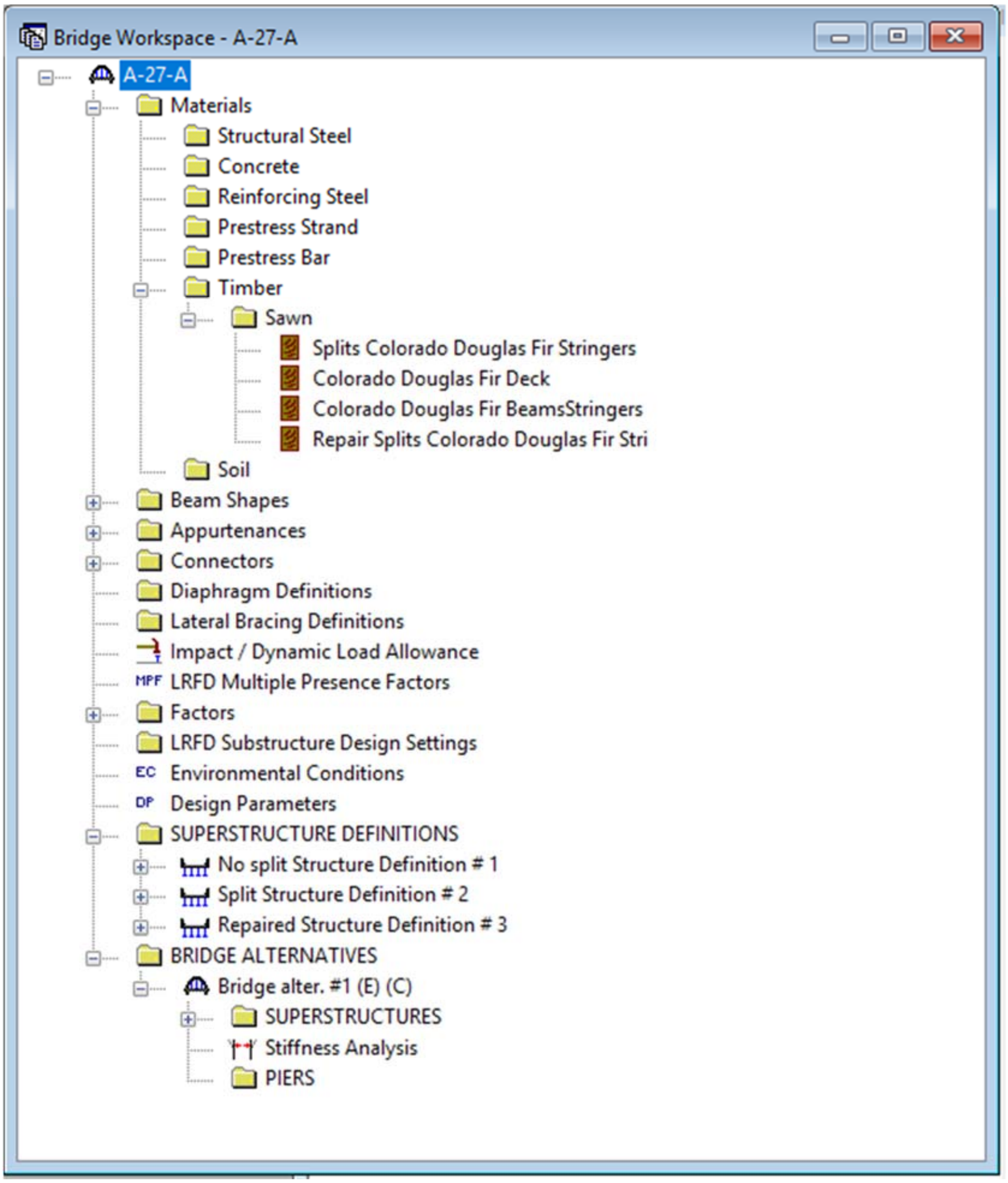


From the bridge explorer, create a new bridge and enter the following information.

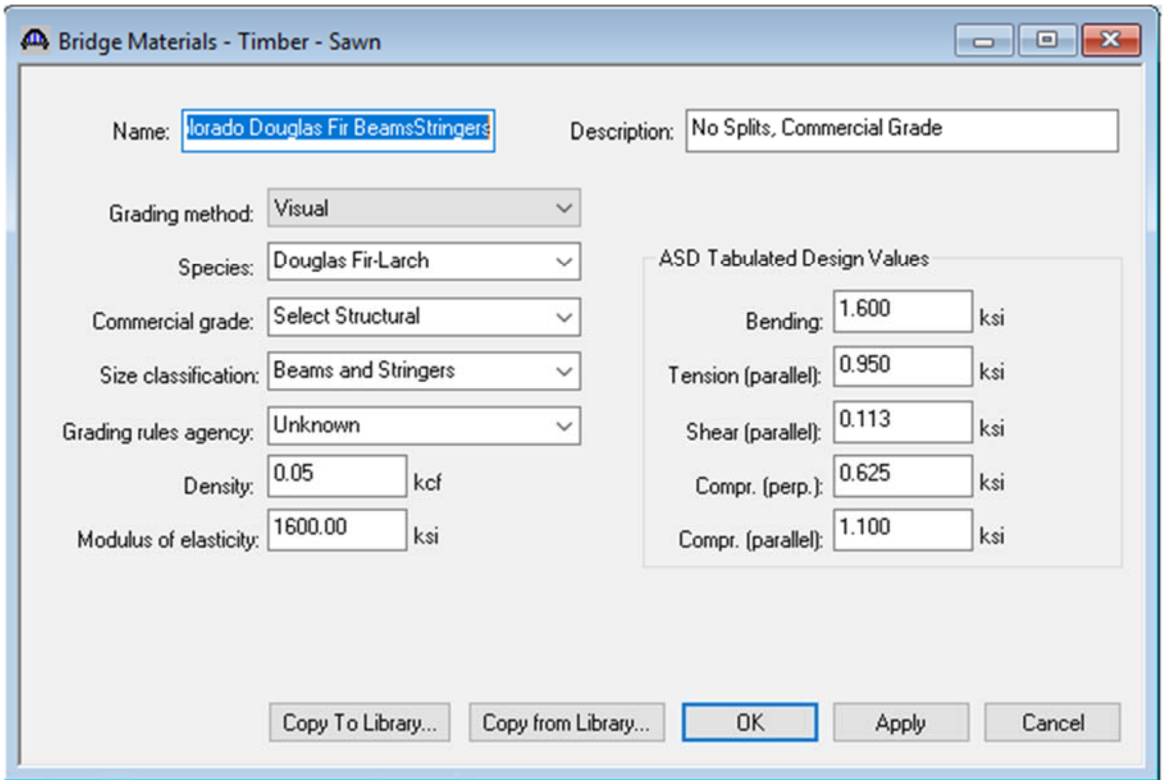


Click OK. This saves the data to memory and closes the window.

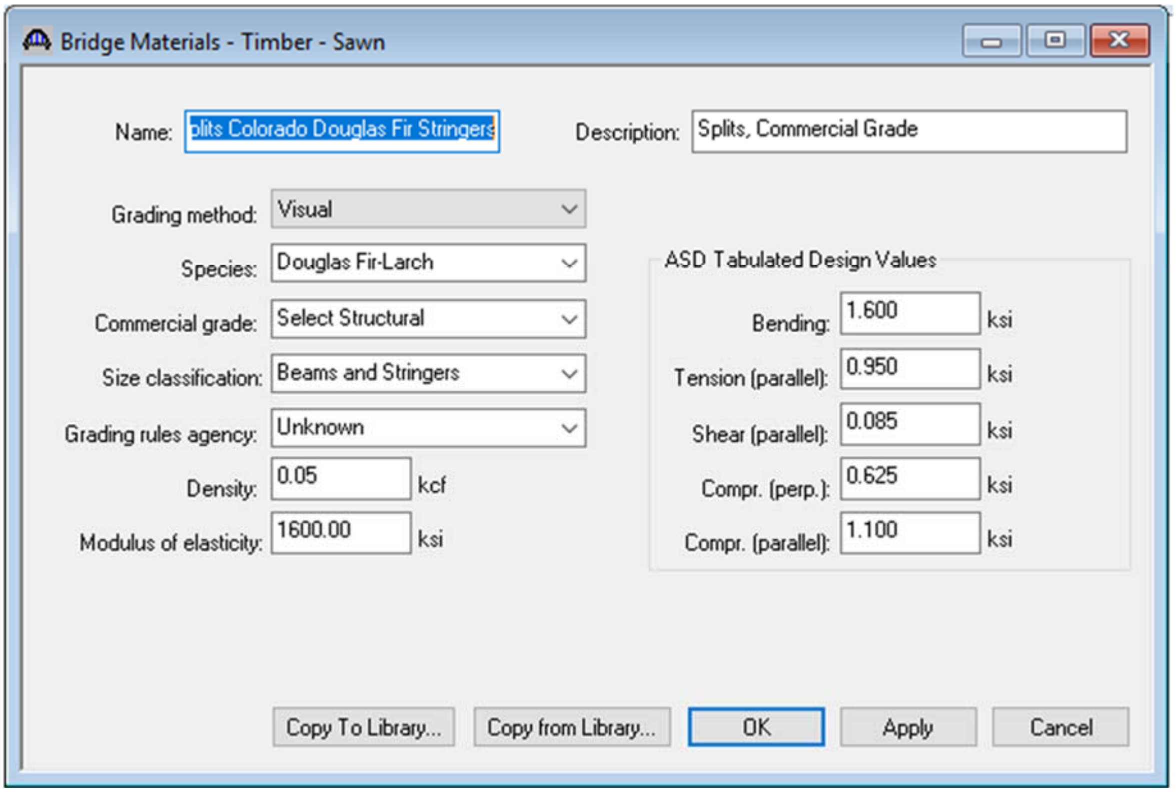
To add three a new timber material, click on Materials, Timber, and Sawn in the tree and select File/New from the menu (or right click on Sawn and select New). Click the Copy from Library button and select the Colorado Douglas Fir Beams Stringers from the library. Click OK and the following window will open. The ASD Tabulated Design Values in this window are based on dry conditions and do not include any adjustment factors based on usage conditions. Make necessary corrections to the allowable bending and shear stress values for No Split, Split and Repaired conditions. Click OK to save these timber materials to memory and close the window.



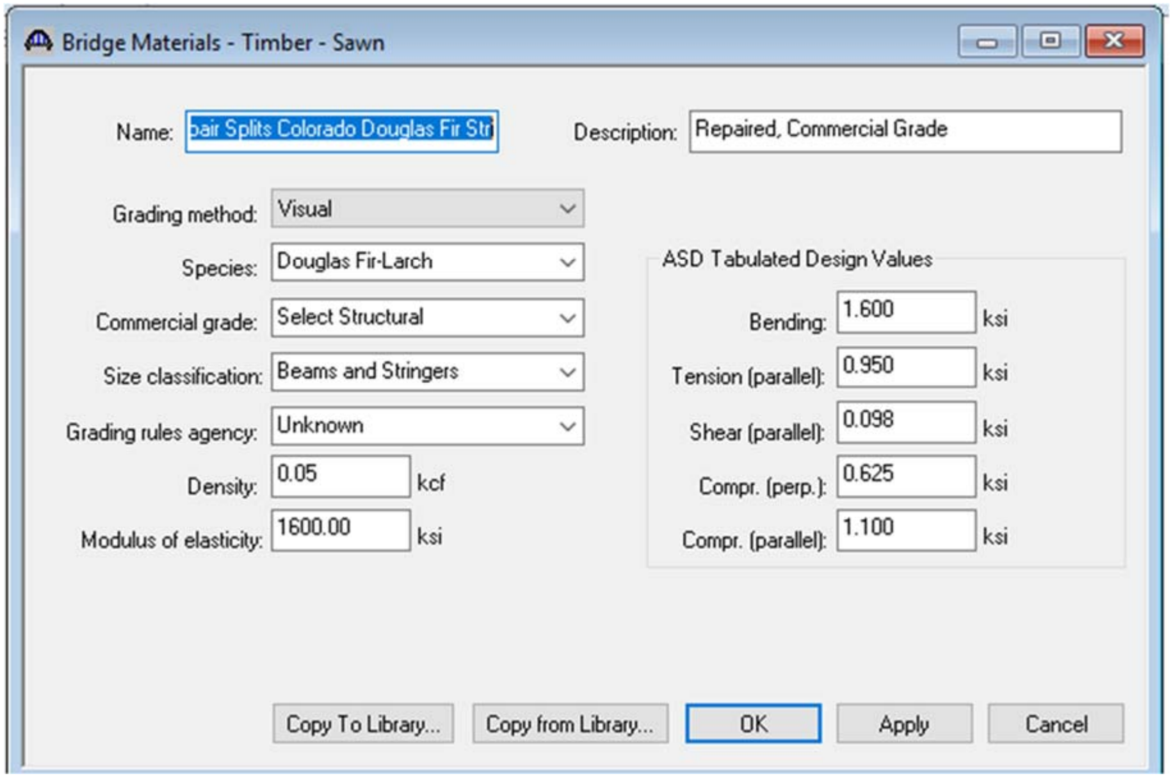
For No split stringer condition materials properties



For split stringer condition materials properties

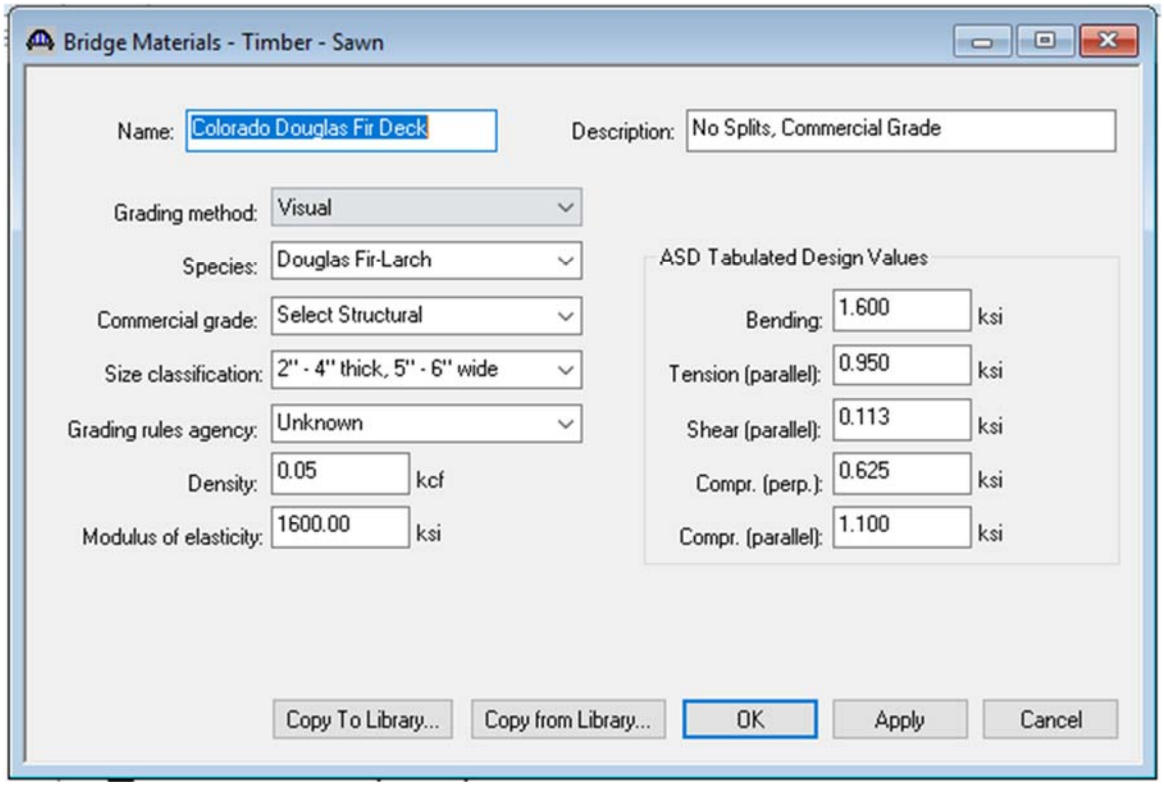


For repaired split stringer condition materials properties

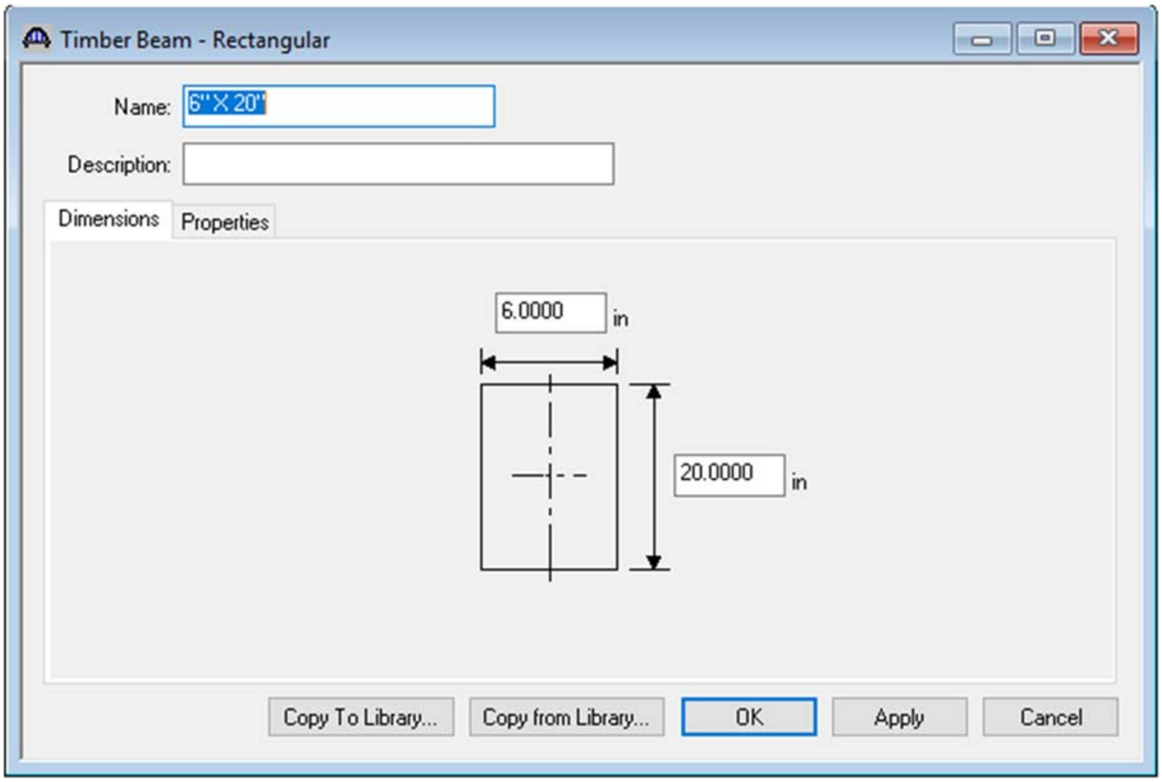


Inventory shear stress for repaired split stringer = *130 / 1.33 = 98 psi
(* see Section 1, Table 1-3)

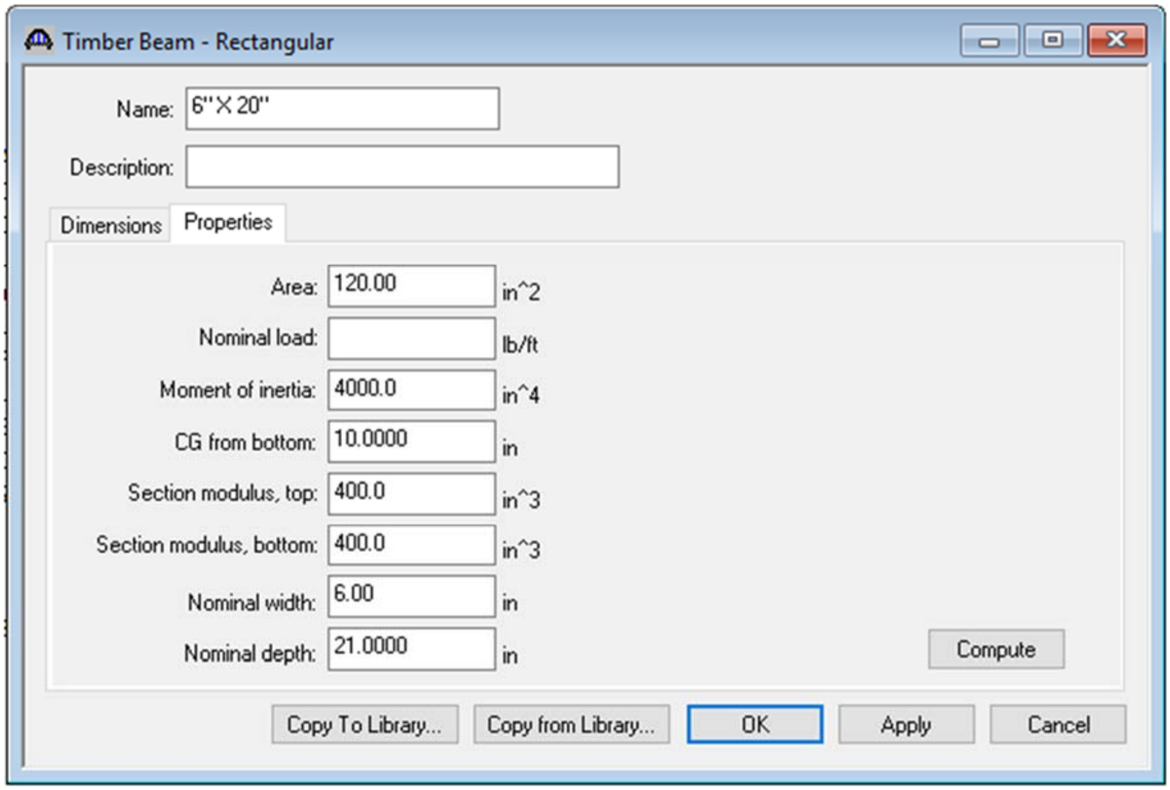
Follow the same procedure to copy from the Materials library. Change the name of material and size classification. Click OK to save this timber deck material to memory and close the window.



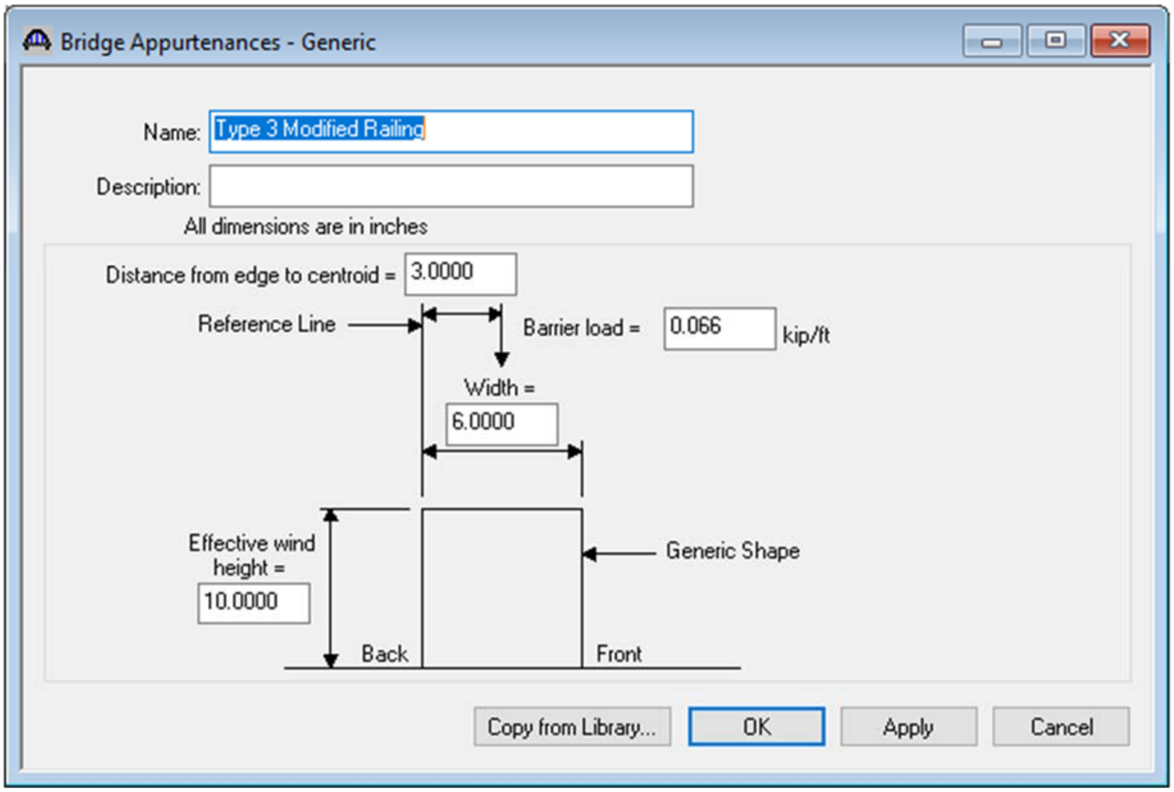
Add a new timber beam shape by clicking on Beam Shapes, Timber, and Rectangular in the tree and selecting File/New from the menu (or double clicking on Rectangular). Enter the final beam dimensions to be used to calculate section properties on the dimensions tab. Dressed dimensions shall not be used. Click OK to save the data to memory and close the window.



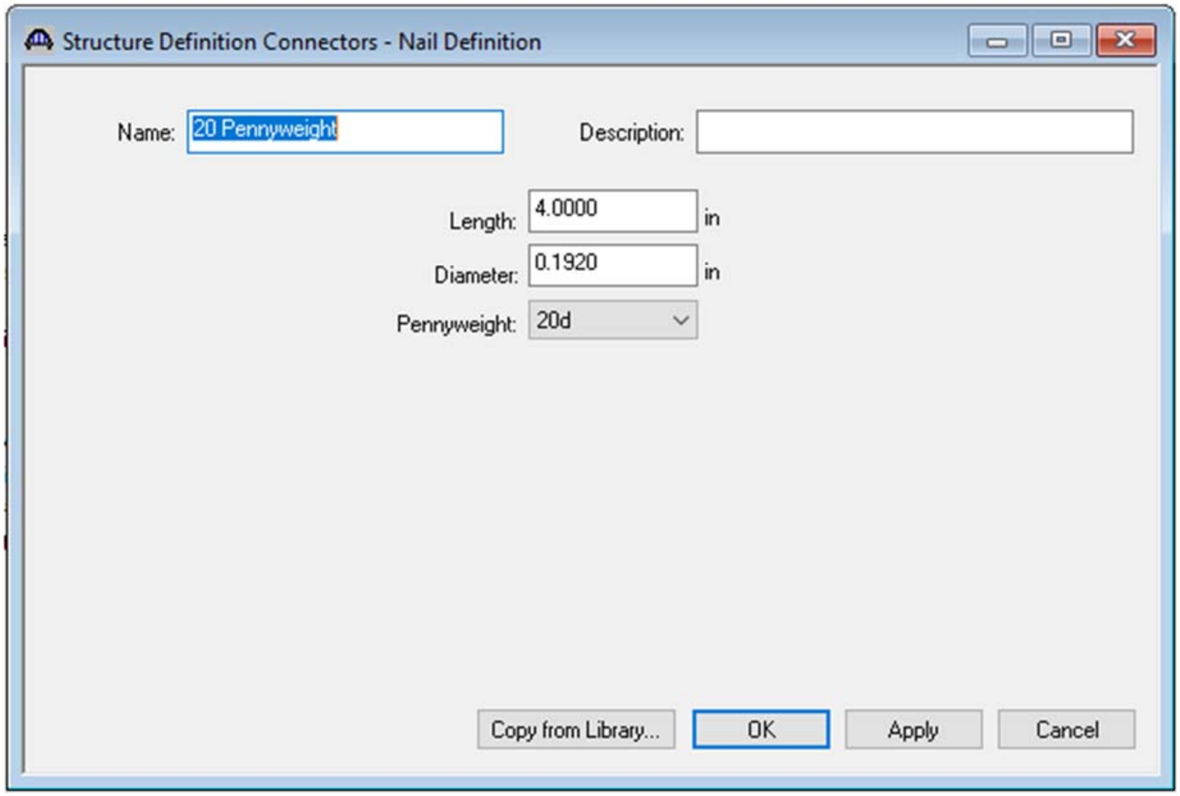
Click the Properties tab, and then Compute. Click OK to save the data to memory and close the window.



Expand the tree labeled Appurtenances to enter the bridge appurtenances information to be used in the analysis. To define a generic railing, double click on Generic in the tree and input the generic railing dimensions. Click OK to save date to memory and close the window.

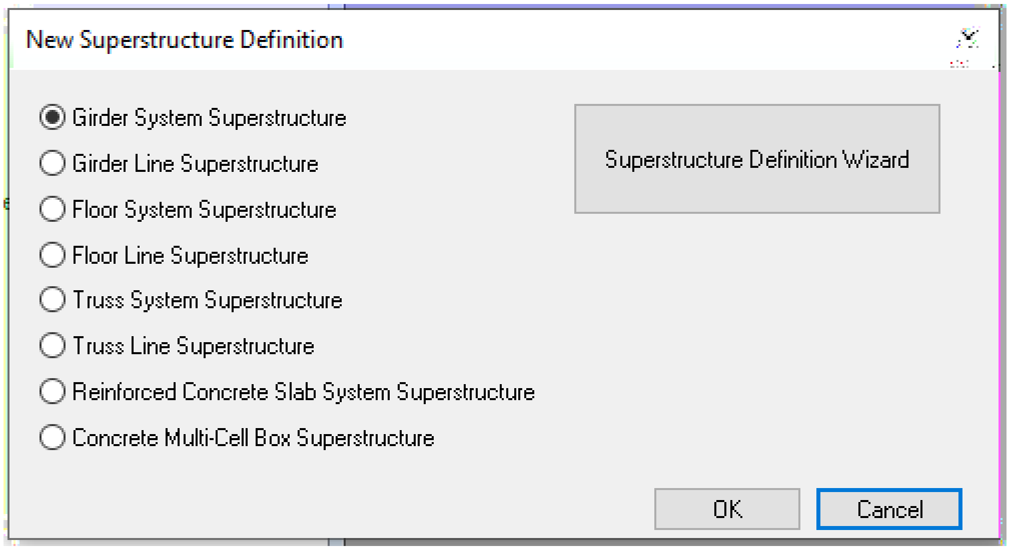


Expand the Connectors tree item to create a nail definition. Double click on Nail. Define the nail and click OK to save to memory.

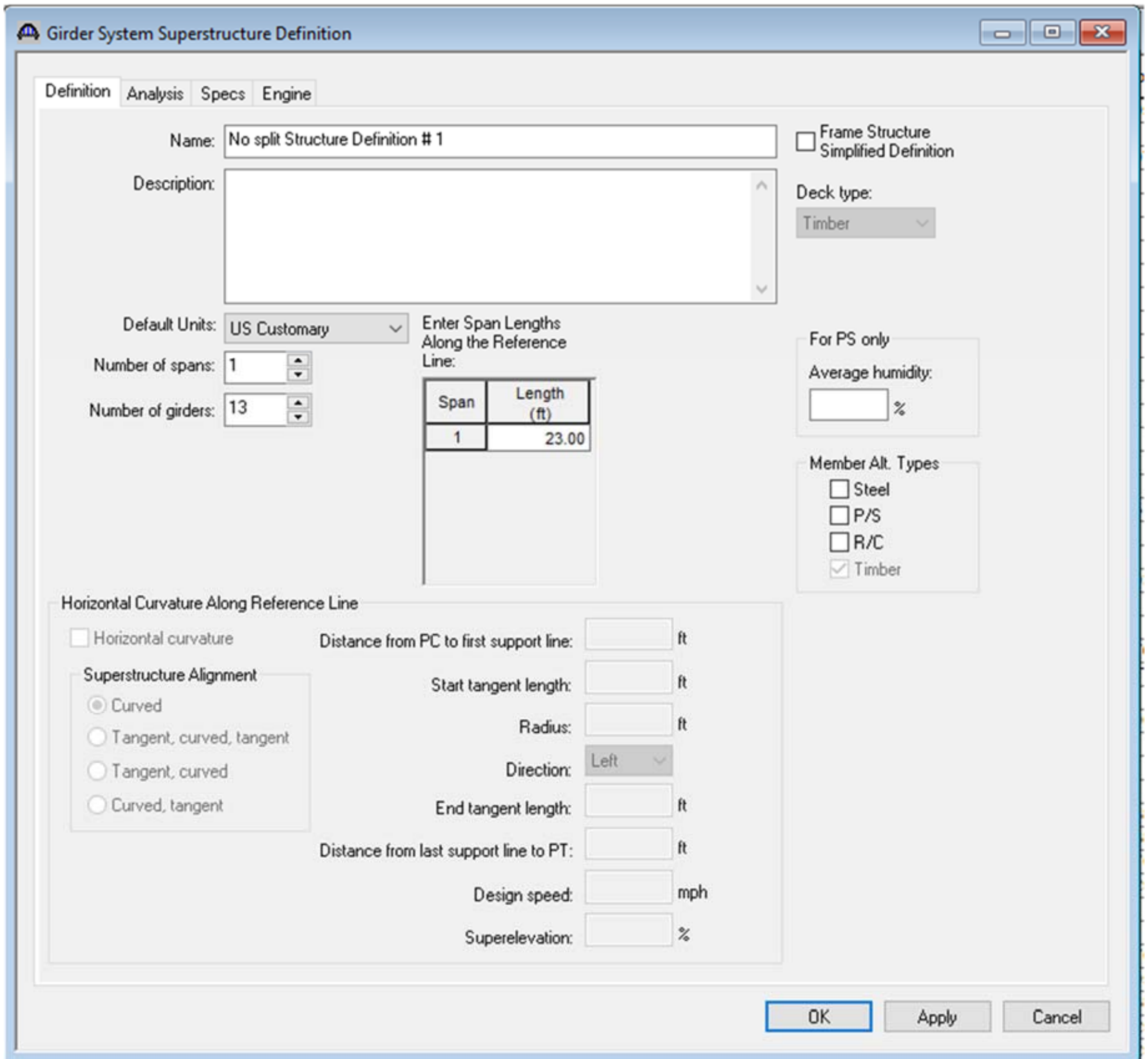


Now that we have created a nail definition, this can be applied to nails in the deck. Reopen the Structure Typical Section: Deck (cont'd) tab. Select the 20 Pennyweight nail definition as the nail on that tab. Click OK to save to memory and close the window.

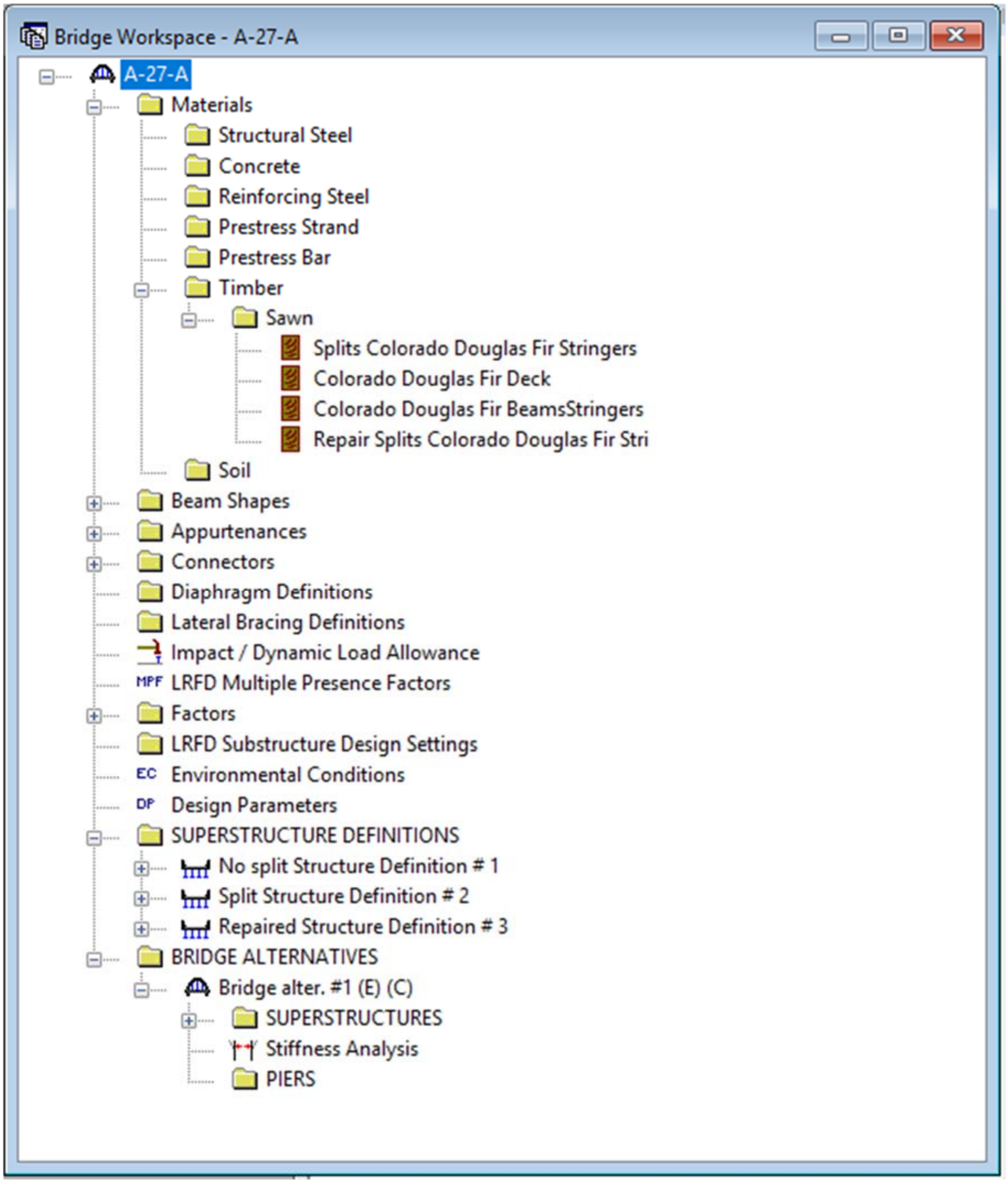
Double click on STRUCTURE DEFINITION (or click on STRUCTURE DEFINITION and select File/New from the menu or right mouse click on STRUCTURE DEFINITION and select New from the popup menu) to create a new structure definition. The following dialog box will appear.



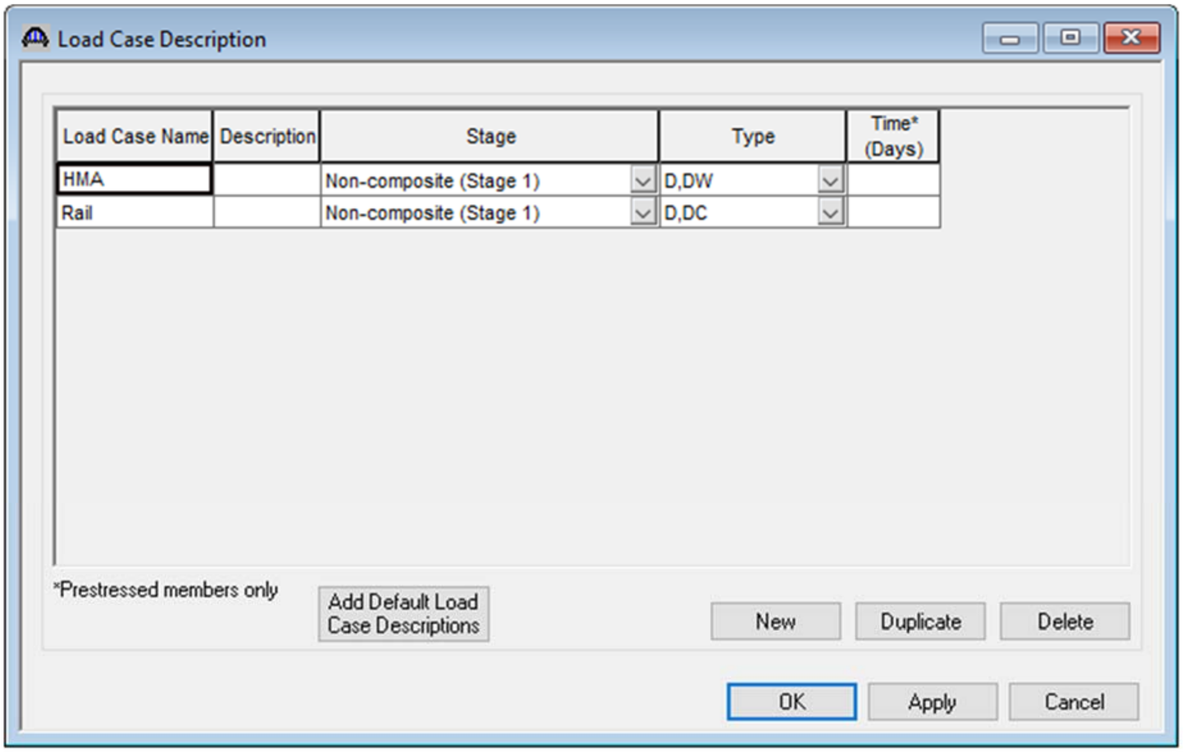
Select Girder System and the following Structure Definition window will open. Enter the appropriate data as shown below.



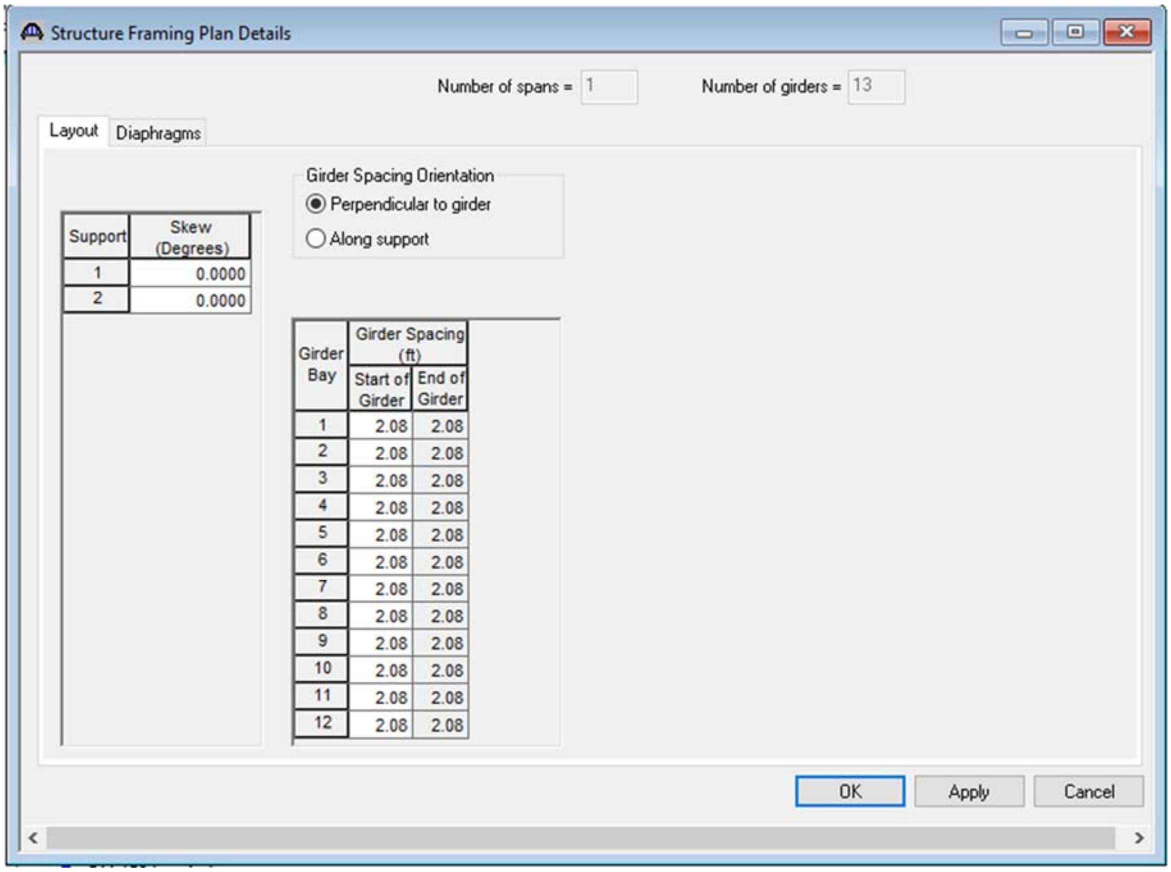
Following is the partially expanded Bridge Workspace tree:



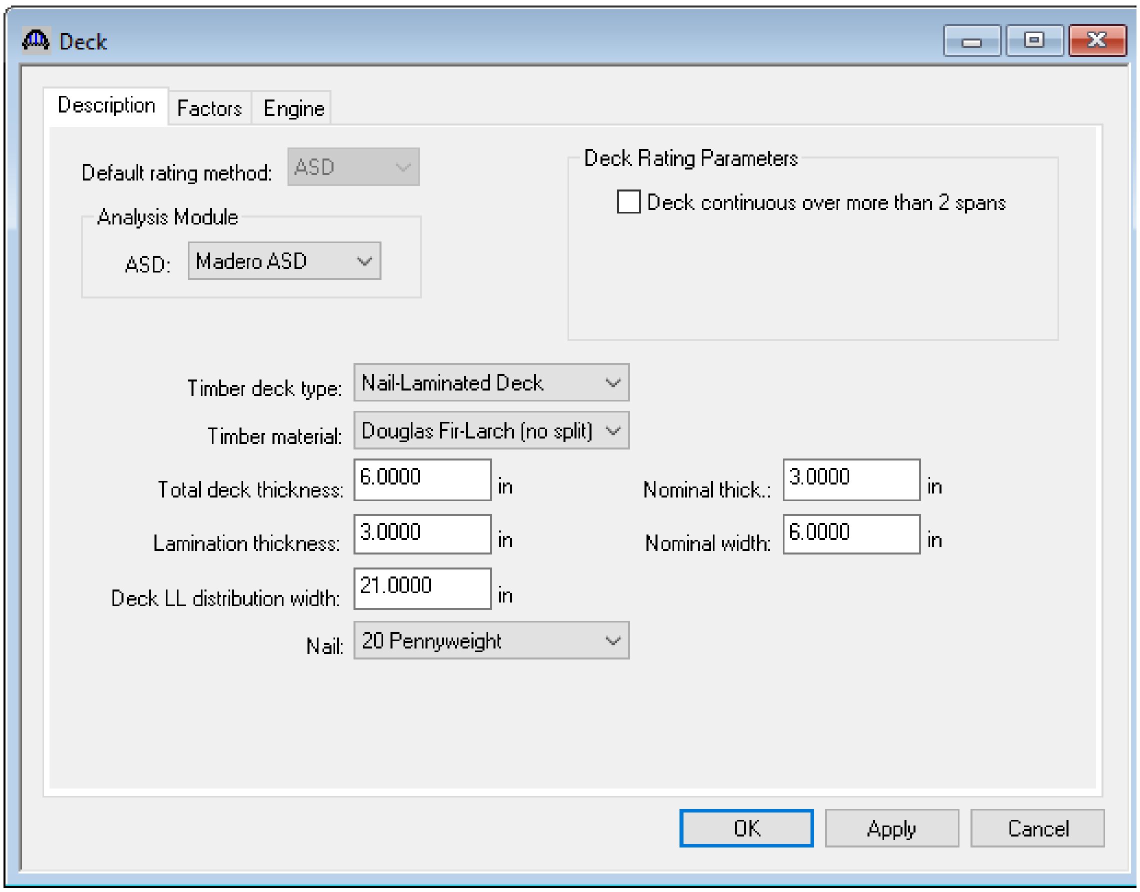
Click Load Case Description to define the dead load cases. The load types are presented in a single row separated by a comma. The first type applies to LFD design and the second type applies to LRFD design and it corresponds with the load types presented in the AASHTO Specifications. The completed Load Case Description window is shown below.



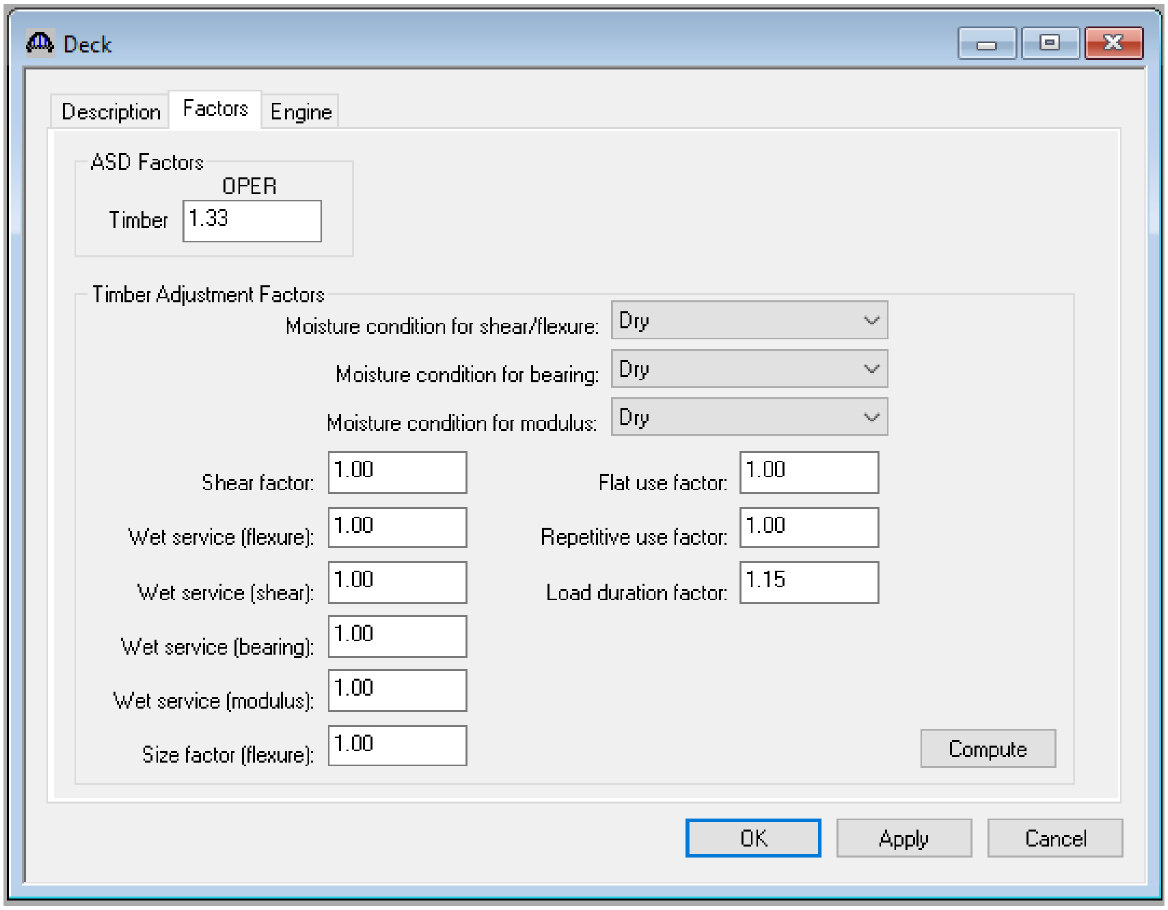
Double click on Framing Plan Detail to describe the framing plan. Enter the appropriate data to describe the framing plan. If the bridge has diaphragms, switch to the Diaphragms tab and enter the appropriate data. Click OK to save to memory and close the window.



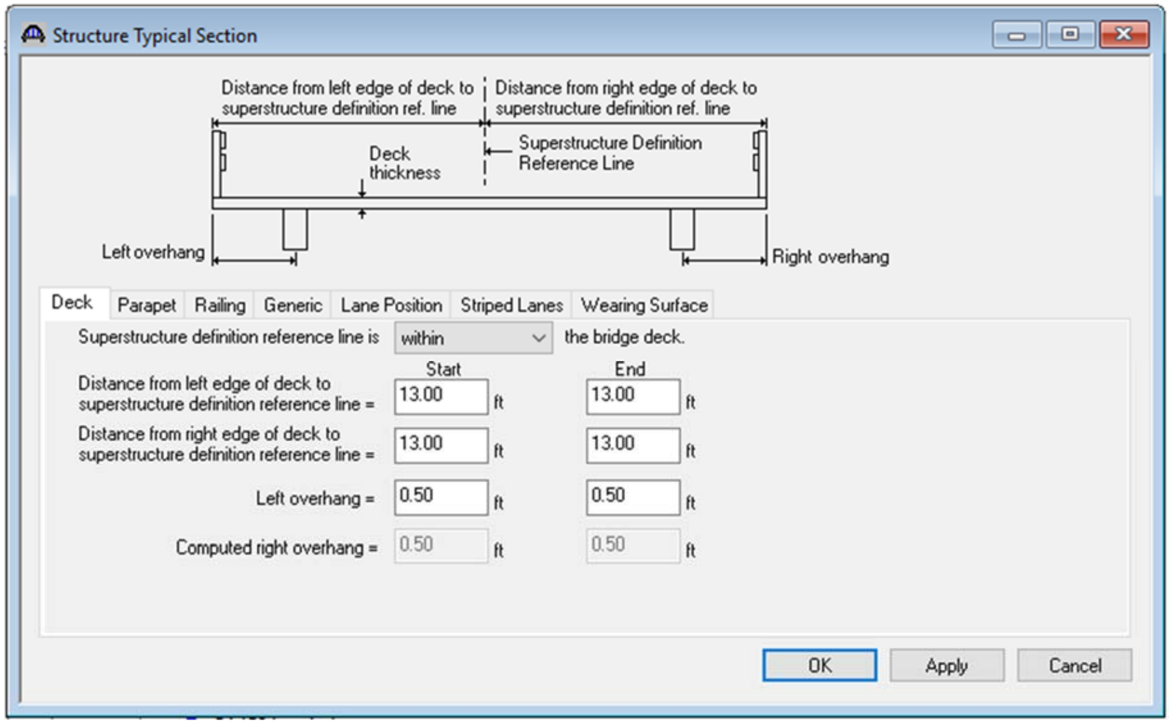
The Deck tab is used to enter information about the deck. BrR only supports transverse timber decks. Select the type of deck as Nail-Laminated. The timber material to be used for the deck is selected from the list of bridge materials described above. A Nail definition has not been created yet, so leave the field blank for now. The Deck LL distribution width in the direction normal to the flooring span shall be per AASHTO Standard Specifications, Article 3.25.1.1. For this structure, this value is equal to 21.0 inches (15 inches plus thickness of floor).



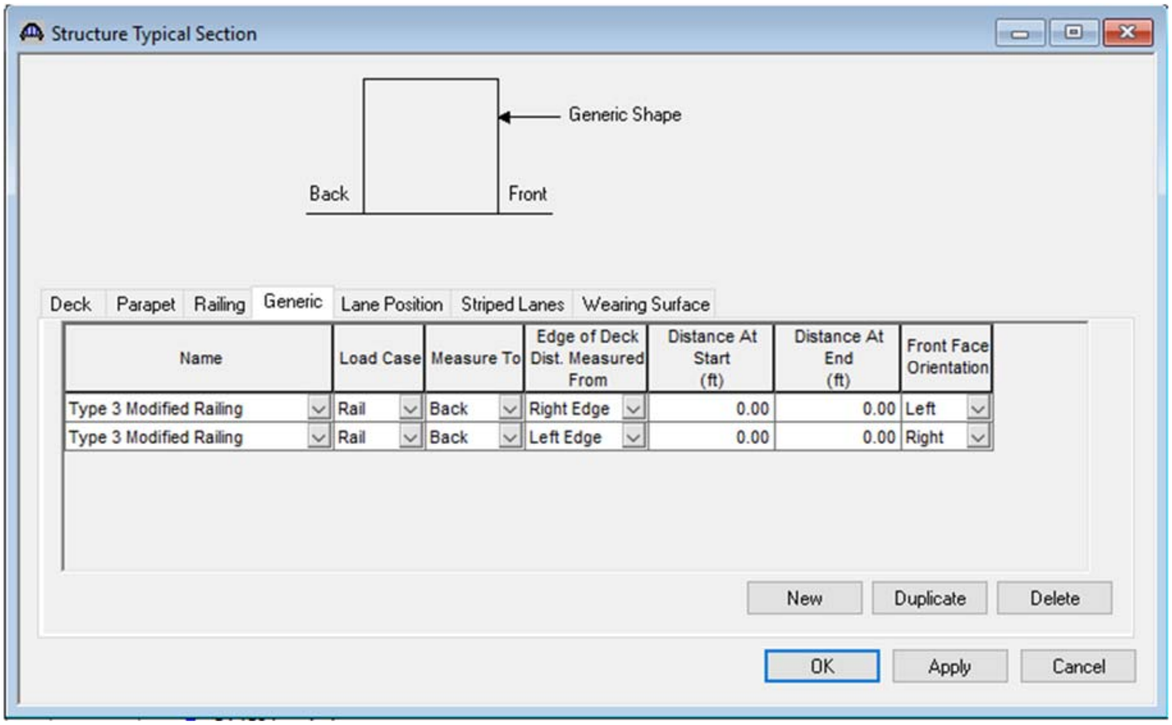
For the Factors tab of the Deck window, factors may be defaulted by using the BrR compute button. In Colorado, dry moisture condition is used.



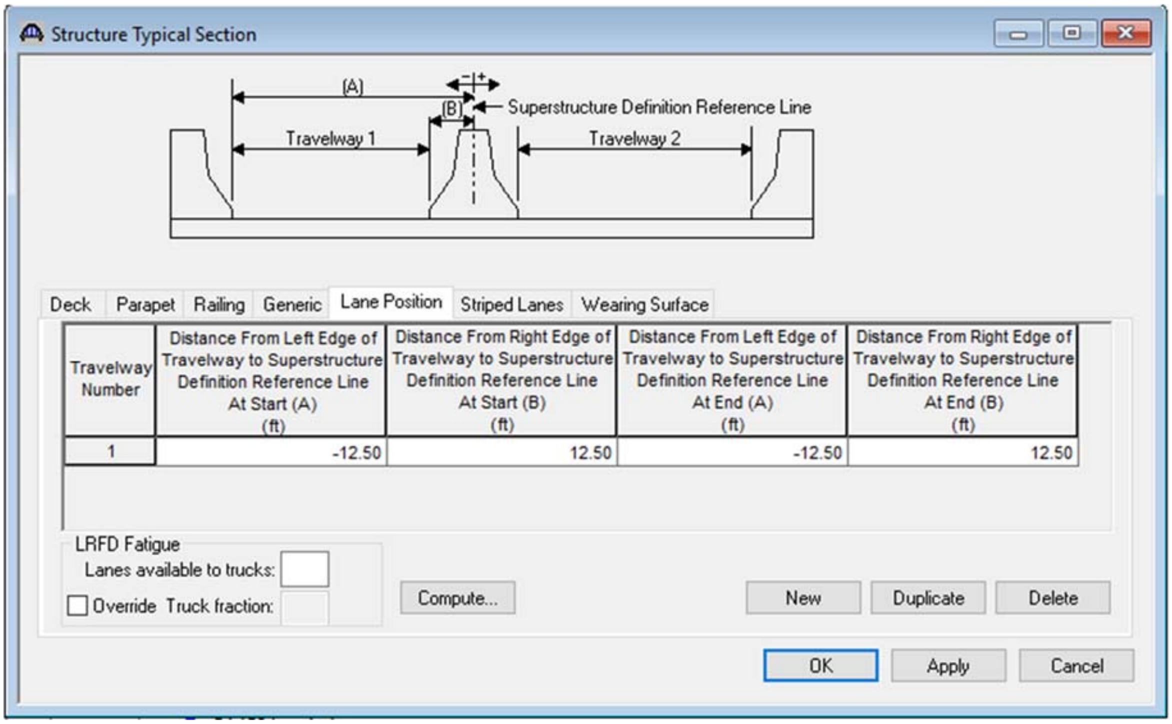
Double click on Structure Typical Section in the Bridge Workspace tree to define the structure typical section. Input the data describing the typical section as shown below.



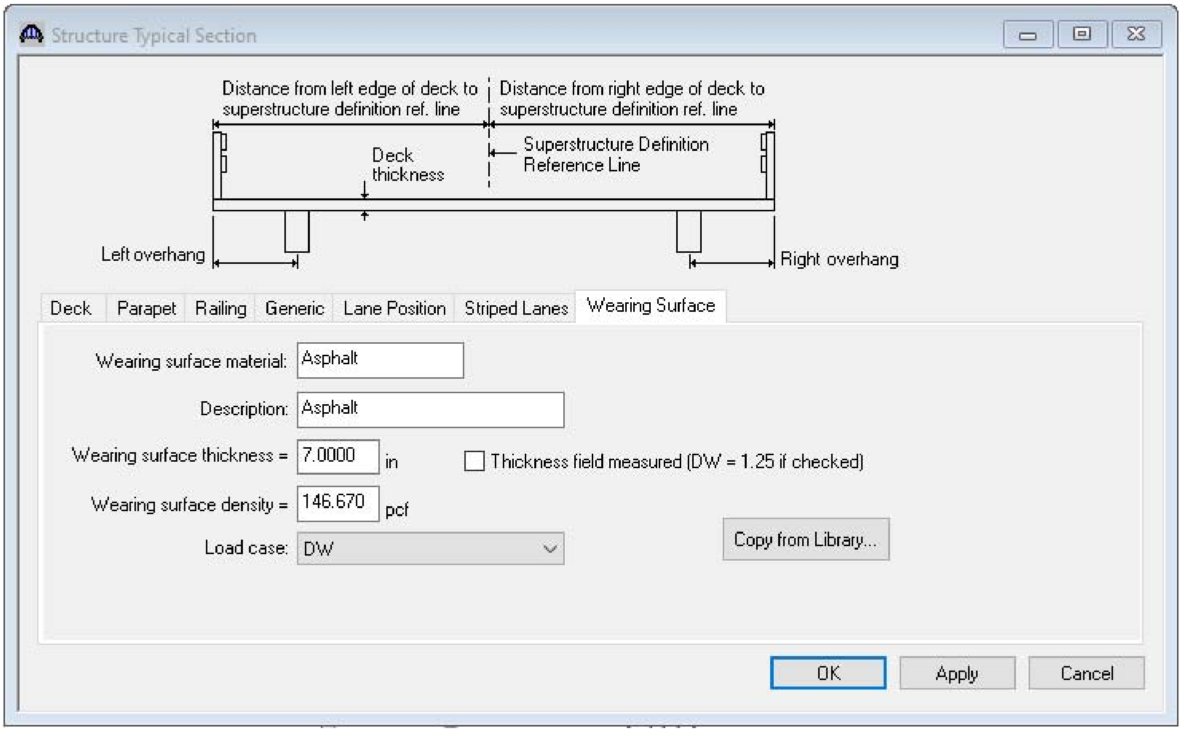
The Generic tab is used to enter information about the appurtenances. Click New to add a row to the table. Enter the following data.



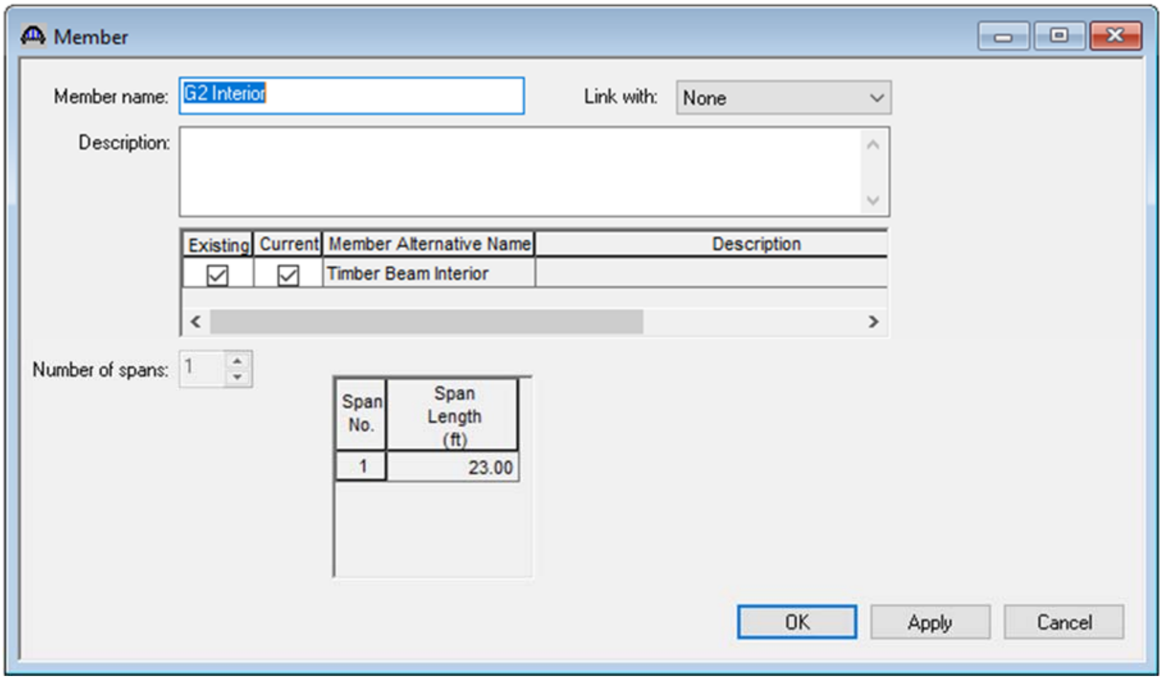
Select the Lane Position tab. Enter the values shown below or click the Compute...button to automatically compute the lane positions. A dialog box showing the results of the computation opens. Click the apply button to apply the computed values.



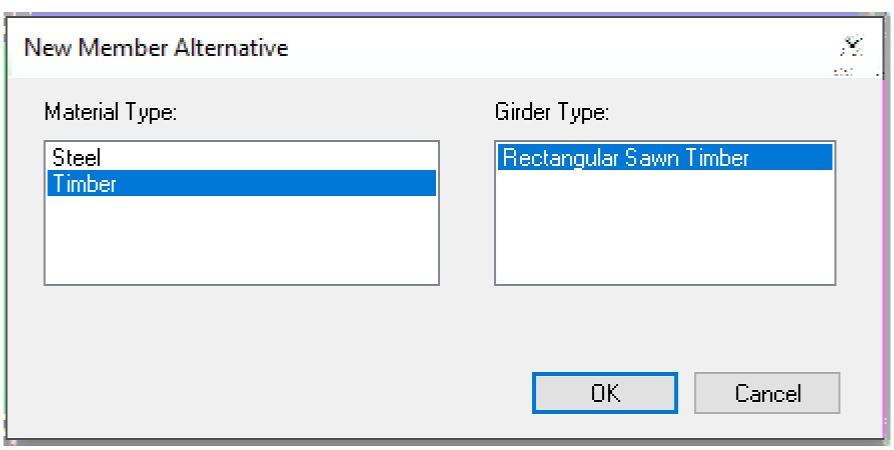
Enter the following wearing surface information and click OK to save to memory and close the window.



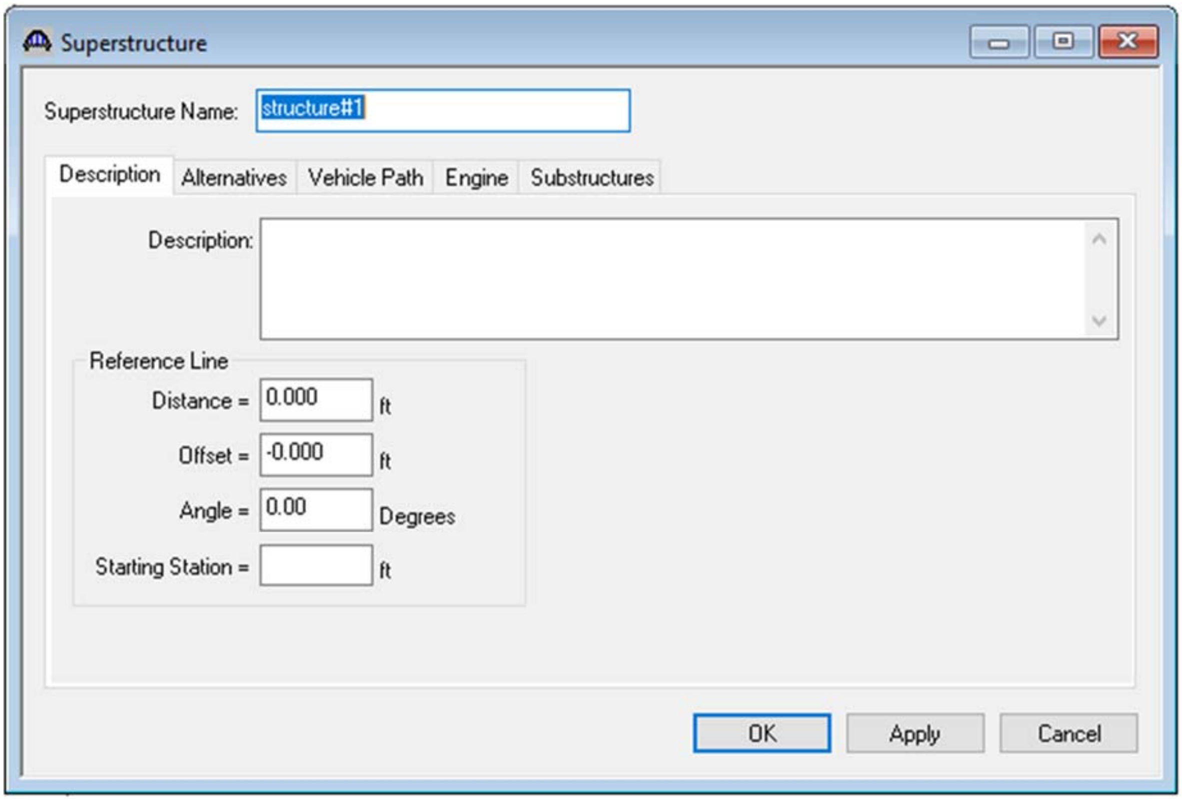
Describing a member:
The member window shows the data that was generated when the structure definition was created. No changes are required at this time. The first Member Alternative that we create will automatically be assigned as the Existing and Current Member alternative for this member.



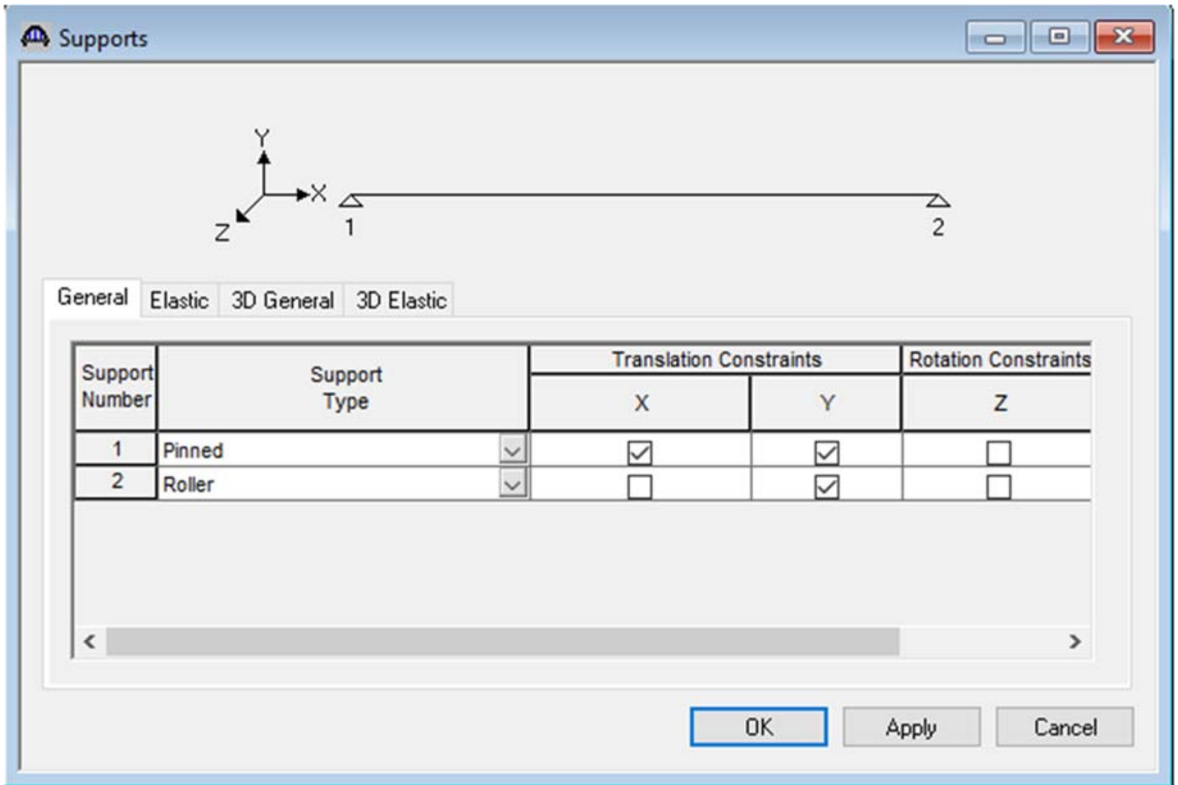
Defining a Member Alternative: Double click MEMBER ALTERNATIVES in the tree to create a new alternative. The New Member Alternative dialog will open. Select Timber for the Material Type and Rectangular Sawn Timber for the Girder Type. Only Timber is available for the Material Type since a timber deck type was selected on the Structure Definition window. Timber decks are limited to timber beams in BrR.



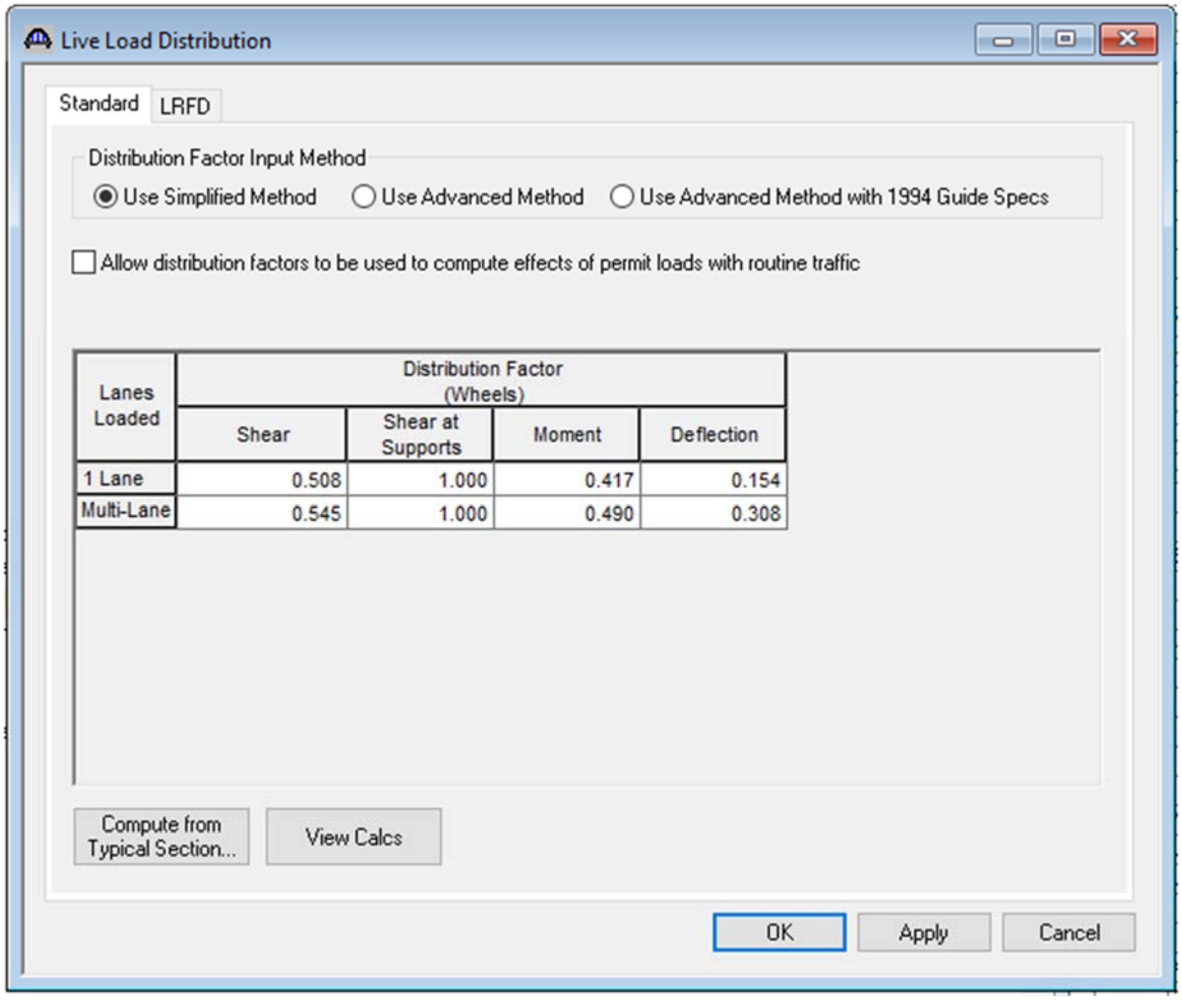
Enter the following data for the Member Alternative. Click OK to save to memory and close the window.



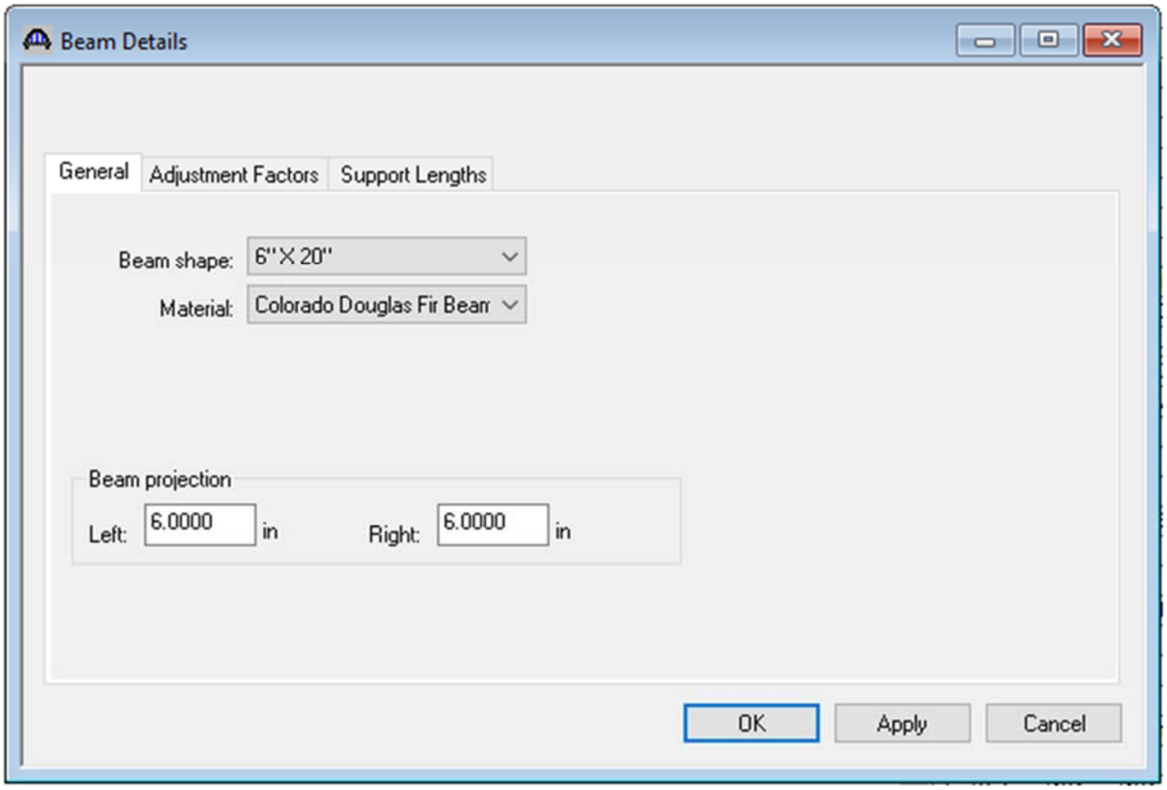
Support constraints were generated when the structure definition was created and are shown below.



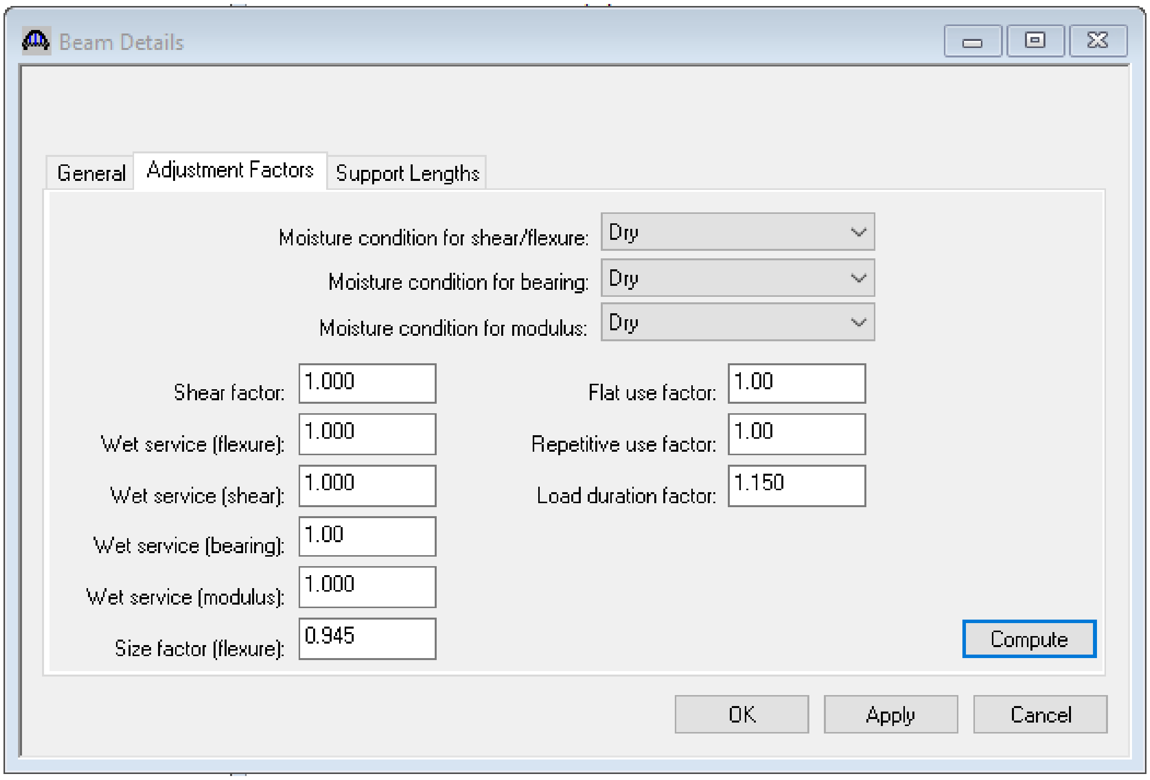
Use the Compute from Typical Section button to compute the live load distribution factors. Refer to AASHTO Table 3.23.1, Article 3.23.1.2 and Article 13.6.5.2.



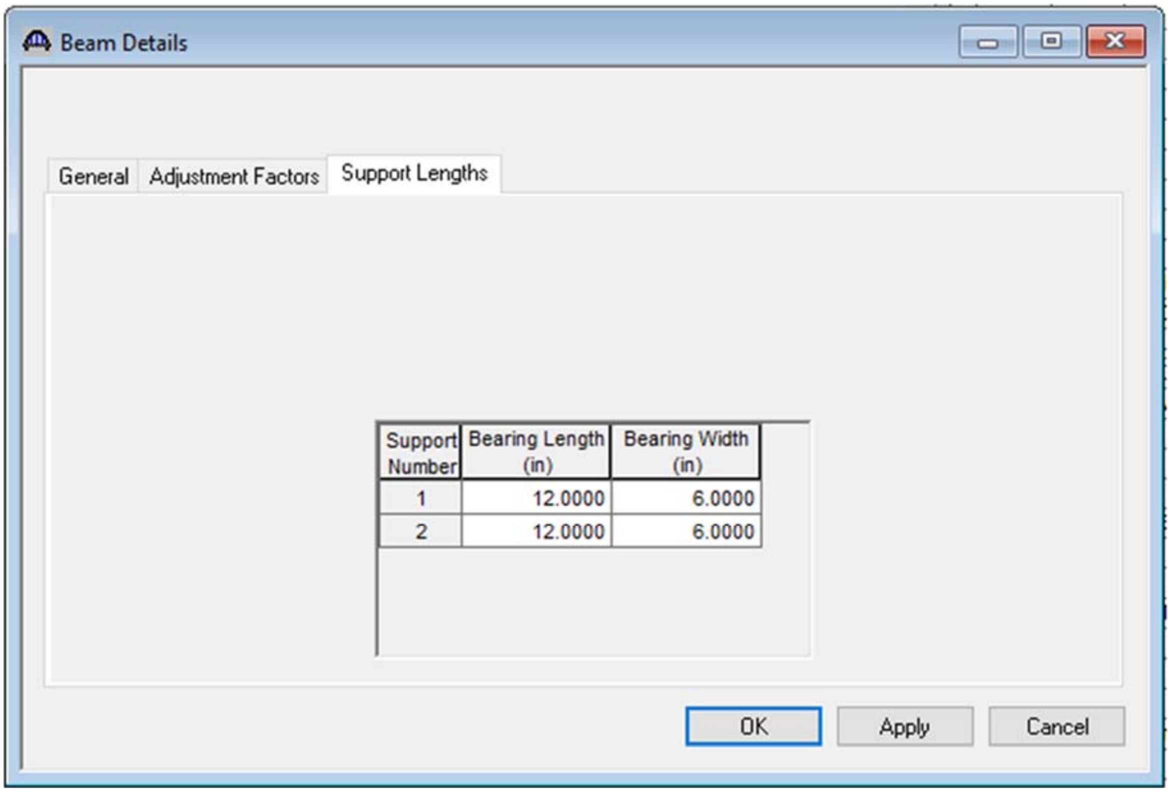
Open the Beam Details window by double clicking on Beam Details in the Bridge Workspace tree. The Beam Details window is shown below.



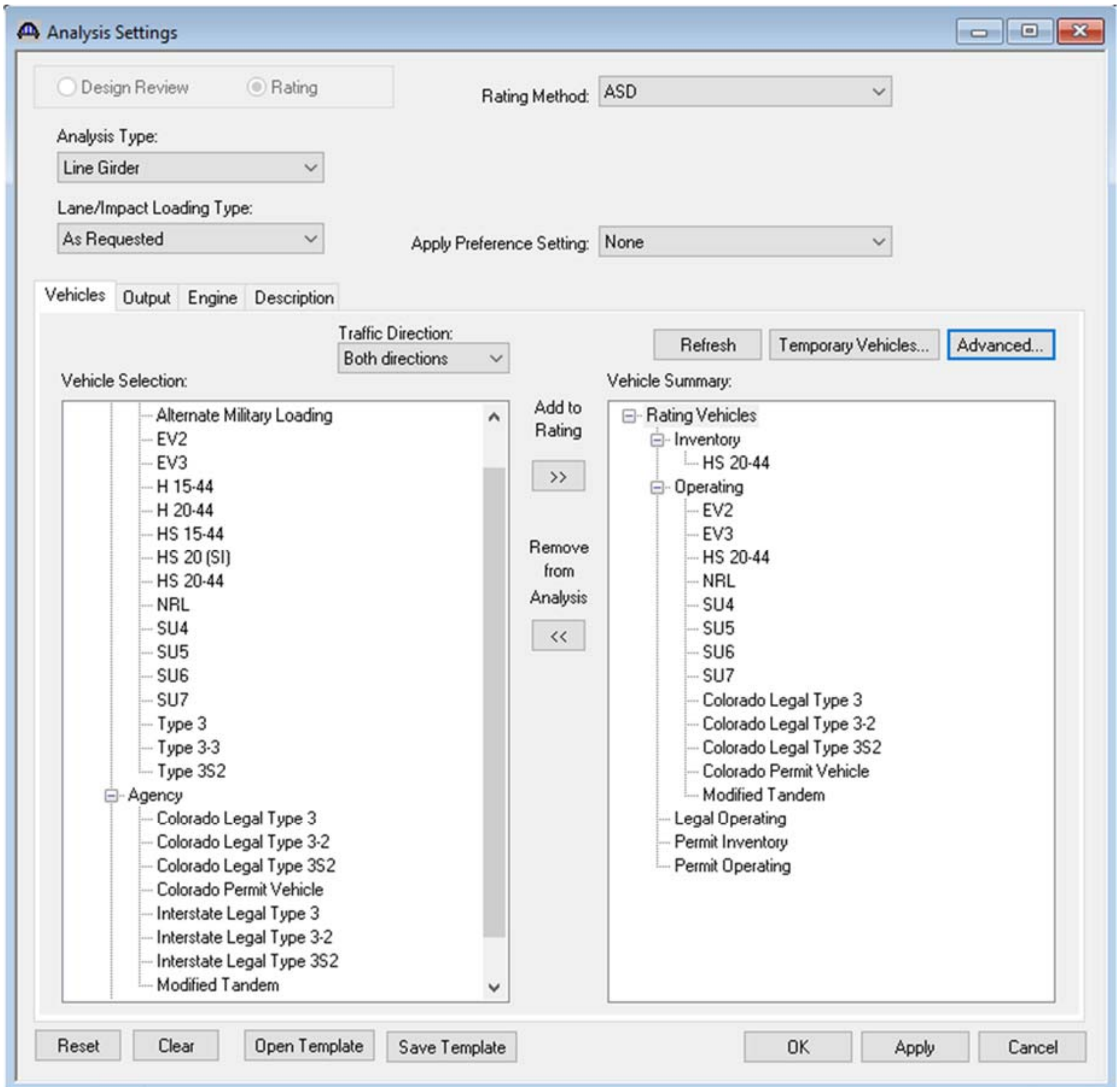
The Adjustment Factors tab of the Beam Details window allows you to enter adjustment factors to modify the tabulated design values entered on the Bridge Materials – Timber – Sawn window. The tabulated design values modified by these adjustment factors produce the design allowable stresses. In Colorado, dry moisture condition is used. Adjustment factors may be defaulted by using the BrR compute button.



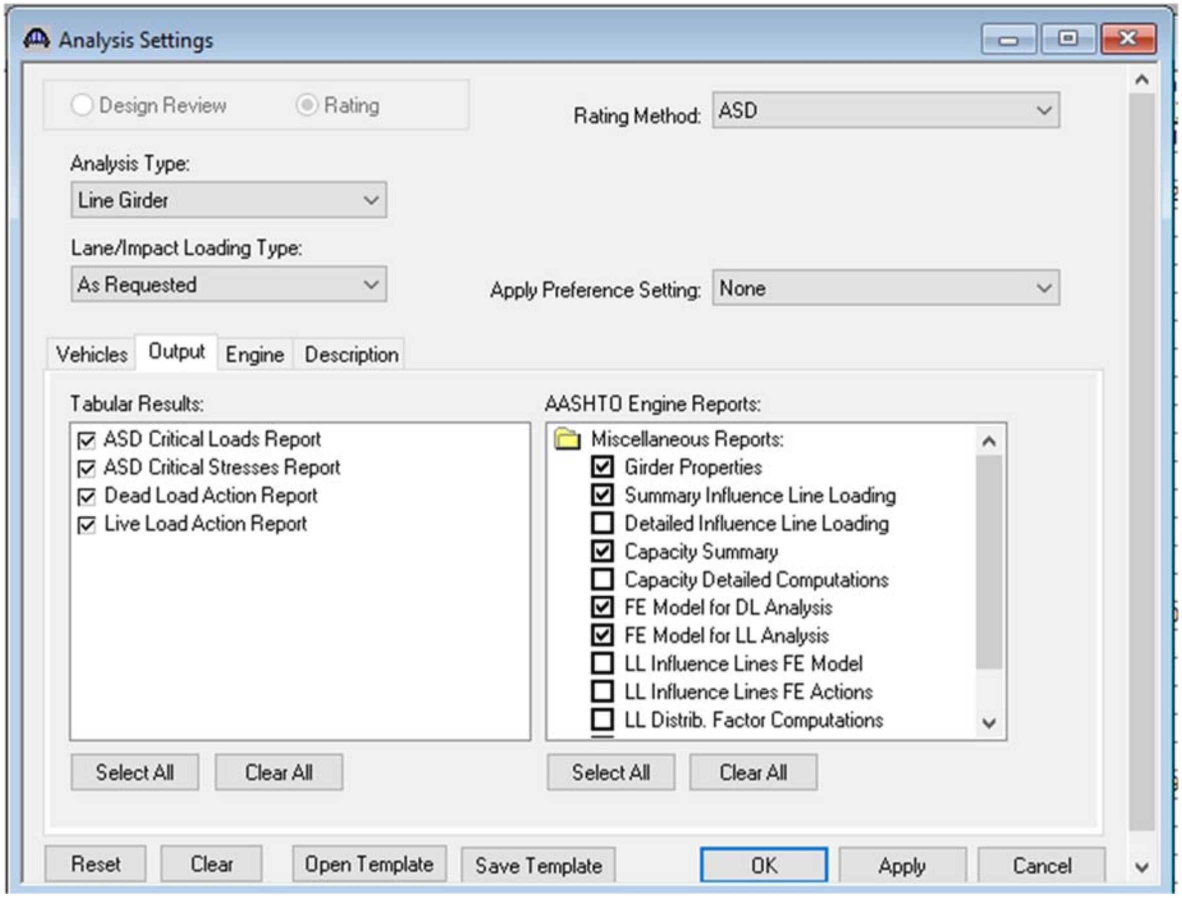
Enter the following data for the Support Lengths tab. Click OK to save to memory and close the window.



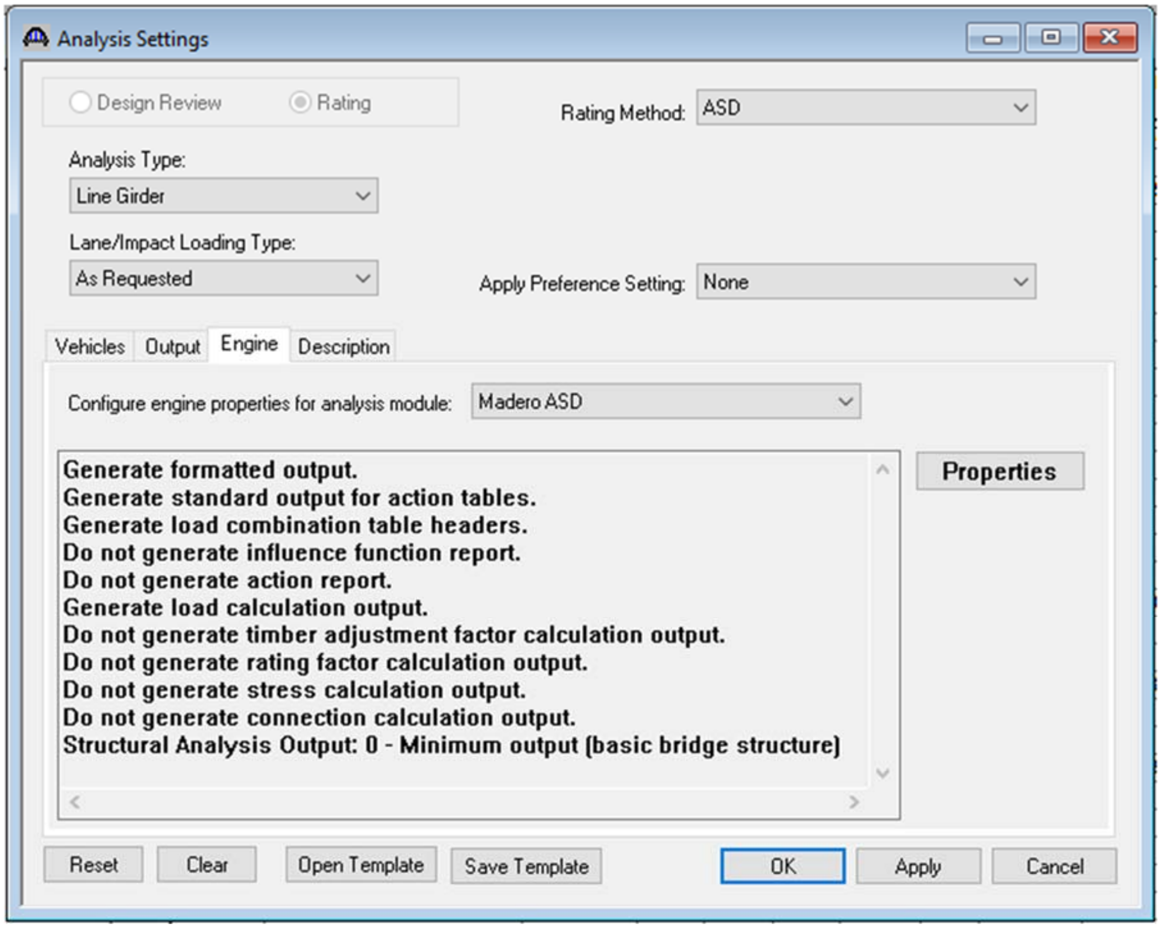
To perform a rating analysis, select the Bridge Analysis Settings button on the toolbar to open the window shown below. Select ASD as the Rating Method, select HS 20-44 vehicle or other vehicles to be used in the rating and click OK.



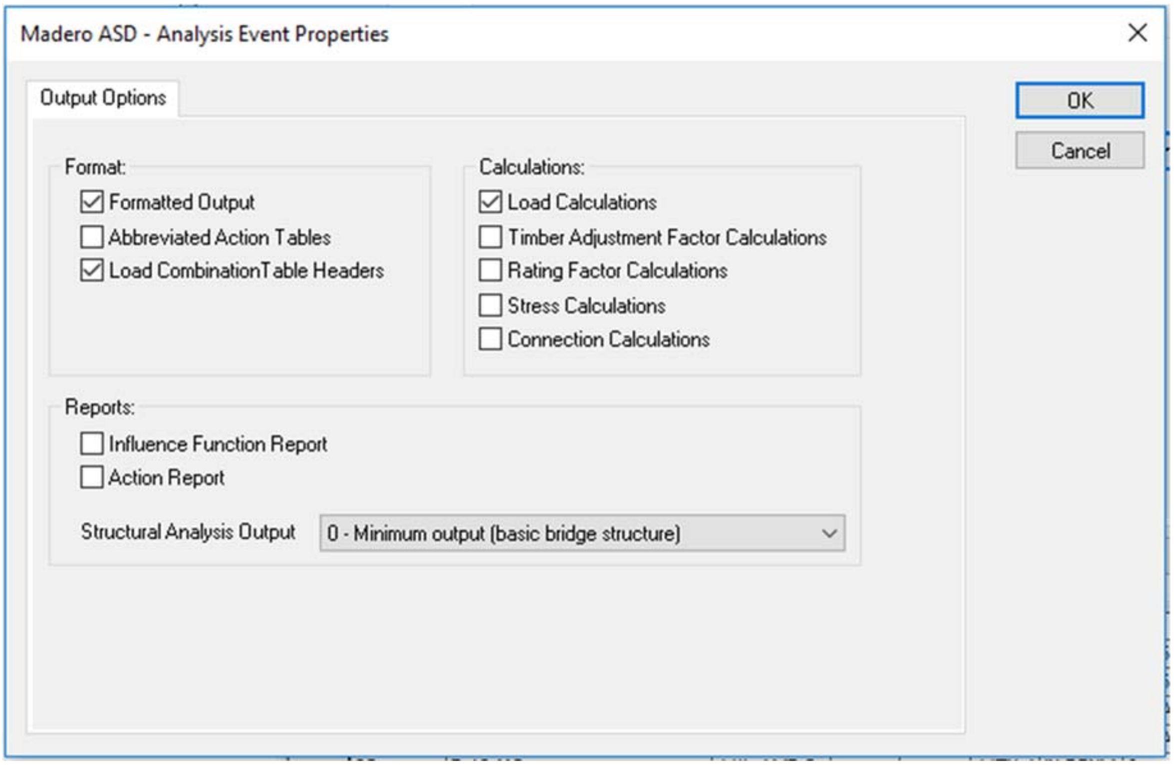
Select the output tab of the Analysis Settings window. Check specific boxes next to the desired output report and click the Engine tab.



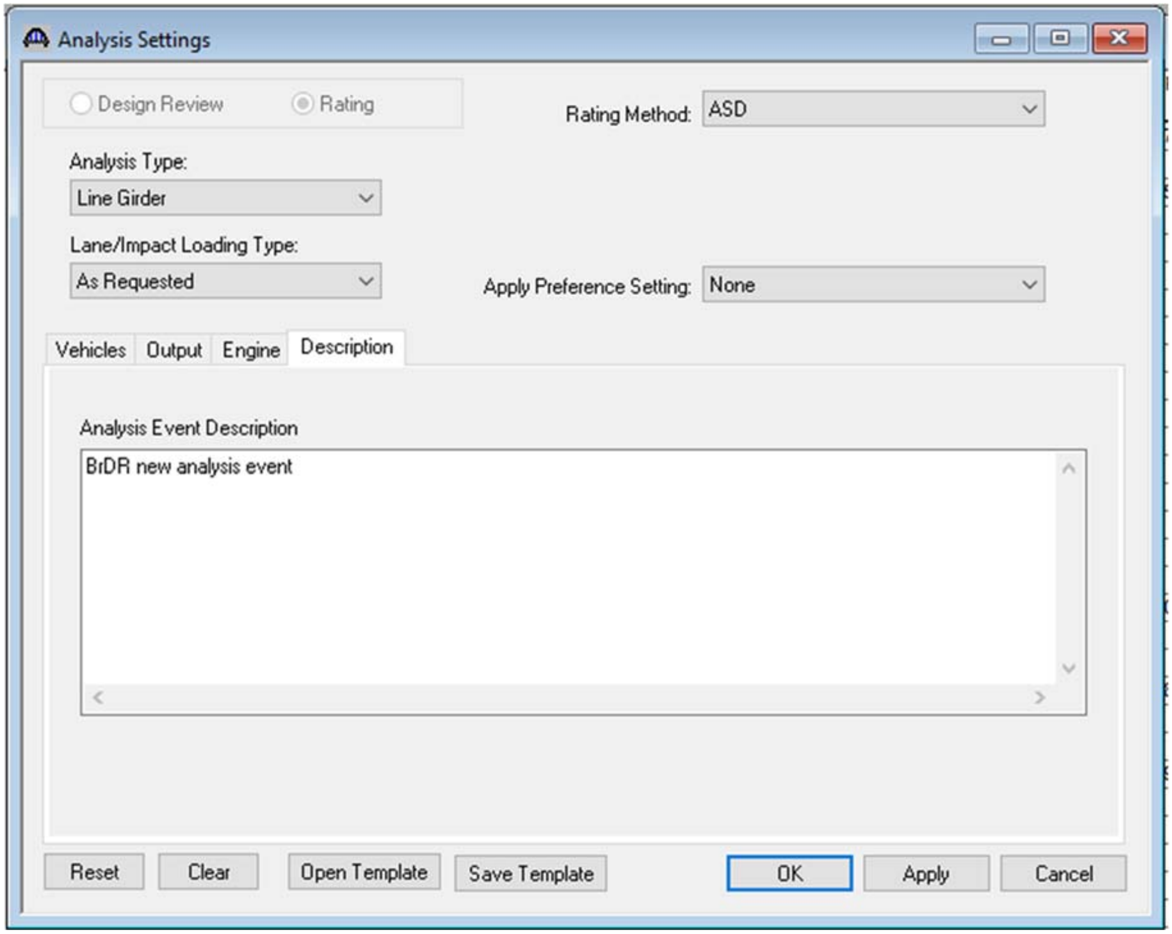
Select the analysis engine and click the Properties tab.



Select the desired Output Options and click OK.



Click the Description tab, provide a general narrative description of the analysis event and click OK.



13.6 CDOT BRIDGE TIMBER RATING PROGRAM DESCRIPTION

The TIMBER computer program performs the complete analysis and rating of simple span timber bridges. The program was developed in accordance with the AASHTO Standard Specifications and the AASHTO Manual for Condition Evaluation of Bridges.

The program will not rate flooring placed longitudinally, splined or doweled flooring, multiple layered decks, nor nontimber decks. In accordance with subsection 13.2, the program does not modify the user input values for allowable stresses.

The program does not consider dead loads other than those caused by the stringers, deck, and overlay. In the case where other dead loads are present that would substantially affect the rating, they shall be accounted for during the analysis.

In the TIMBER program, the nail laminated and plank timber decks shall be rated for non-continuous between stringers while the BrR program rates for continuous. Conventionally, the TIMBER program shall be used for conservative.

The asphalt overlay depth is used to compute the dead load, using the asphalt unit weight of 146.67 pcf. When the timber bridge has gravel overlay (unit weight = 120 pcf) the depth entered should be the equivalent depth of asphalt to gravel. This is done by taking the actual depth of gravel, dividing it by 1.2, and entering the result into the required depth column. The actual depth of gravel shall be shown on the Rating Summary Sheet.

The following information appears as output from the program.

13.6.1 Stringer (For Information Only)

The Bridge Rating Program shall not use for stringer rating. The BrR program shall be used for timber stringer ratings.

A) Total dead load moment and shear for the stringer being rated.
B) Live load moment and shear due to HS 20 truck.
C) Stringer rating for bending and shear for Inventory and Operating stress levels.
D) Live load moment and shear due to all three Colorado posting trucks.
E) Posting ratings for bending and shear for all three Colorado posting trucks. If all posting rating values are greater than the respective posting truck weights, and the operating rating is greater than or equal to 36 tons, then the posting ratings are not printed.
F) The Overload Color Code Rating for the stringer being rated is based on either shear or bending, depending on which controls.

13.6.2 Decking

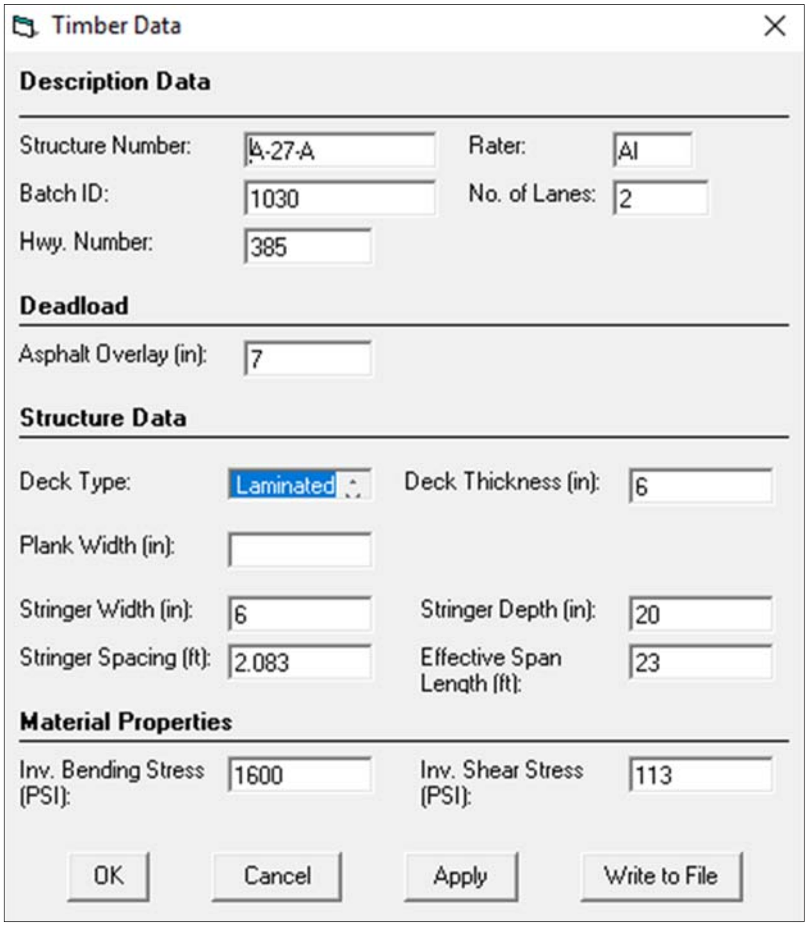
A) Deck rating for nail laminated and plank floors at Inventory and Operating stress levels. Only design vehicle deck load ratings shall be reported in the RSS.

B) Posting ratings for all three Colorado posting trucks do not need to report in the RSS.

C) The Overload Color Code Rating is not a function of the deck rating.

13.7 TIMBER BRIDGE DECK RATING EXAMPLES

Timber Rating Program Input:



Timber Rating Program Output:

```
Batch: 1030          Timber Bridge Rating        Date: 6/13/2019
Rater: AI           Structure Number: A-27-A    State Highway: 385

 Number of Lanes: 2
 Floor Type:  Laminated
 Effective Span Length: 23.000 ft.
 Stringer Spacing: 2.083 ft.
 Stringer Width: 6.000 in.
 Stringer Depth: 20.00 in.
 Floor Thickness: 6.00 in.
 Bituminous Overlay Thickness: 7.00 in.
 Allow. Stress in Bending: 1600.0 PSI
 Allow. Shear Stress: 113.0 PSI

 HS-20 Truck (Gross Wt. 36 Tons)

 Deadload Moment:    17.77 KIP-ft.
 Liveload Moment:    45.09 KIP-ft.
 Deadload Shear:      1.75 KIPS
 Liveload Shear:      8.34 KIPS

                    Inventory           Operating
                    Rating              Rating

 Deck Rating        134.5 Tons          179.1 Tons

 Stringer
    Bending          28.4 Tons           42.4 Tons
    Shear            31.5 Tons           44.3 Tons

 Moment Capacity     53.33 KIP-ft        70.93 KIP-ft
 Shear Capacity       9.04 KIPS          12.02 KIPS


 + + + Overload Information + + +
 +                              +
 +   Color Code = White         +
 +                              +
 +   1-Axle (KIPS) =  44.388    +
 +   2-Axles (4-0) =  53.245    +
 +   3-Axles (4-0) =  57.788    +
 +   4-Axles (4-0) =  67.282    +
 +                              +
 +   These Loads Assume 1-Lane  +
 +      Distribution Factor     +
 ++++++++++++++++++++++++++++++++
```

COLORADO DEPARTMENT OF TRANSPORTATION

TIMBER RATING SUMMARY

Structure #	A-27-A
State Highway #	385
Batch I.D.	1030
Structure Type	TTS
Parallel Structure #	NONE

Rated using:

Asphalt thickness: 7 in.

- ☑ Colorado legal loads
- ☐ Interstate legal loads
- ☐ Multi-lane for Legal & Permit Vehicles
- ☑ Single lane for Legal & Permit Vehicles

Structural Member	No Split Int Girder	Split Int Girder	Repaired Int Girder	Deck	
	Tons				
Inventory	27.6	21.8	21.8	134.5	
Operating	40.5	32.6	39.3	179.1	
Type 3 truck	35.3	27.9	33.6		
Type 3S2 truck	54.4	43.0	51.9		
Type 3-2 truck	56.1	44.4	53.5		
Type SU4 truck (27T)		28.9	34.8		
Type SU5 truck (31T)		31.0	37.4		
Type SU6 truck (35T)		34.8	40.1		
Type SU7 truck (39T)		38.8	44.7		
NRL (40T)	46.3	39.1	46.2		
EV2 (28.75T)	36.2	28.6	34.5		
EV3 (43T)	36.8	29.1	35.1		
Permit Truck (96T)	84.9	70.9	84.7		
Modified Tandem (50T)	50.0	39.5	47.6		

Comments:

Allowable Bending stress=1600 psi
Allowable Split Shear stress =85 psi
Allowable Repaired Split Shear stress =97.74 psi
Color Code:YELLOW Based on modified tandem for Repaired stringers
Re-rated per request from the Inspection Team. More than 25% of the girders are splits and/or repaired.

Rated with BrR v6.8.2 for Timber girders

PE Seal

Rated by: (Print name and sign)	Date:	Checked by: (Print name and sign)	Date:

CDOT Staff Bridge - ASR 02/2017

13.8 GUIDELINES FOR SISTER BEAM RATING

The term “Sister Beam” is used when a new steel beam/section or a new timber stringer is added to an existing timber structure, and placed adjacent to or side-by-side an existing damaged or deteriorated timber stringer, to add structural capacity or carry the existing stringer load.

Adding a Sister-Beam to an existing structure is a major rehabilitation and should be designed and rated using LRFD and LRFR methods respectively.

AASHTOWare BrR software should be used for the rating.

The existing timber stringers shall be rated using ASD method with single lane loaded for Legal Load vehicles and Colorado Permit vehicles. The new sister-beam/s shall be rated using LRFR method with single lane loaded for Legal Load vehicles and Colorado Permit vehicles. The Live Load Impact shall be considered for the sister-beam, but not for the timber stringer. The entire structure should be rated in both ASD and LRFR for the existing stringers and new sister-beam/s respectively.

Substructure does not need to be rated except as requested by the Bridge Inspection Engineer.

The Rating Summary sheet shall show both the existing stringers and the new sister-beam ratings and denote the controlling one.

Major and Minor timber structures with sister-beam/s should be rated the in same manner in accordance with this section.

Damaged / Deteriorated stringer covers stringers that have been evaluated as broken, checked, cracked, split, or decayed stringer. Existing timber stringers condition evaluation should follow Subsection 13-3 and 13-4.

The rater and checker shall complete the rating documentation as described in Section 1 of the Bridge Rating Manual. Any variation from the original design assumptions shall be added to the Rating Summary Sheet as applicable. The rating package requirements shall be per Section 1.13 and Section 1.14 of the Bridge Rating Manual and as amended herein.

The Designer should review the superstructure rating to make sure it meets the design’s load path and assumptions.

13.8.1 LIVE LOAD DISTRIBUTION

Matching the existing stringers deflection, stiffens, and load path should be considered when adding a structural support or a sister beam. To maintain the existing structure behavior and load path, the new sister beam is usually designed to match the existing stringers deflection, stiffness, depth, etc.

The load sharing between the new sister-beam and the damaged / deteriorated existing stringer can be calculated in different way. Different load sharing calculation could result in different LLDF between the new and other existing stringers. The designer should be consulted in verifying the intent of the design, the LLDF calculation methodology, and the final load distribution factors.

Based on the provided load sharing example in this section and other load sharing calculations, in most cases, the damaged/deteriorated stringer carries about 10% to 20% of the load while the new sister-beam carries the rest. On the long term, the damaged/deteriorated stringer might continue to lose its capacity and the new sister-beam may be required to carry all the dead and live load. To minimize repetitive ratings, the new rating should ignore any capacity of the damaged/deteriorated stringer and apply all the load to the new beam, unless otherwise approved in advance by CDOT Staff Bridge Rating Engineer.

For consistency among ratings and for simplification purposes, distribution factors should be calculated based on average girder spacing since the spacing can differ. (In reality, the spacing might have not changed much considering the damaged/deteriorated timber stringer still exist).

The existing sound timber stringers should be the controlling stringers in the rating. The design should be re-evaluated if otherwise.

Service-II Limit State is intended to control the yielding of steel and slip-critical connections. It is considered to be midway between Service-I and Strength-I Limit States. Service-II usually does not control non-composite, non-compact steel sections. Accordingly, Service-II rating maybe ignored when rating steel sister-beam structures, (Reference AASHTO LRFD 9th edition and MBE 3 Edition).

Below is an example calculation of live load sharing between a split timber stringer and a new steel sister-beam. The rater and designer should convene to insure consistency between the rating and the design intent.

Sharing Live Load

The spacing between the sister beam and the split timber stringer is close (side by side). Therefore, the deflection of sister beam shall be the same as the split timber stringer.

Sister beam:

$$Deflection_S = \frac{P_S \cdot L^3}{48 \cdot E_S \cdot I_S}$$

Split timber:

$$Deflection_T = \frac{P_T \cdot L^3}{48 \cdot E_T \cdot I_T}$$

$$Deflection_S = Deflection_T$$

$P_S + P_T$ = 100% of wheels load. It is shared between split timber stringer & sister beam.

$$\frac{P_S \cdot L^3}{48 \cdot E_S \cdot I_S} = \frac{P_T \cdot L^3}{48 \cdot E_T \cdot I_T} \quad \text{or} \quad \frac{P_S}{E_S \cdot I_S} = \frac{P_T}{E_T \cdot I_T}$$

Timber stringer: $h_T := 20 \cdot in$ $\quad b_T := 6 \cdot in$ $\quad$ Sister beam: HSS 12 x 8 x 5/16

$E_S := 29000 \cdot ksi$ $\quad E_T := 1600 \cdot ksi$

$I_S := 224 \cdot in^4$ $\quad I_T := \left(b_T \cdot \frac{\left(\frac{h_T}{2}\right)^3}{12} \right)$ $\quad I_T = 500\ in^4$ (Worst case when the split is at mid-high)

$P_S := 100\% \cdot \frac{(E_S \cdot I_S)}{(E_S \cdot I_S + E_T \cdot I_T)}$ $\quad P_S = 0.89$

$P_T := 100\% - P_S$ $\quad P_T = 0.11$

The steel sister beams shall be rated with the LRFR mehod. Use AASHTO Table 4.6.2.2.2a-1 to determind the moment and shear LLDF for interior steel beam with plank wood deck.

Type of Deck	Applicable Cross-Section from Table 4.6.2.2.1-1	One Design Lane Loaded	Two or More Design Lanes Loaded	Range of Applicability
Plank	a, l	S/6.7	S/7.5	$S \leq 5.0$

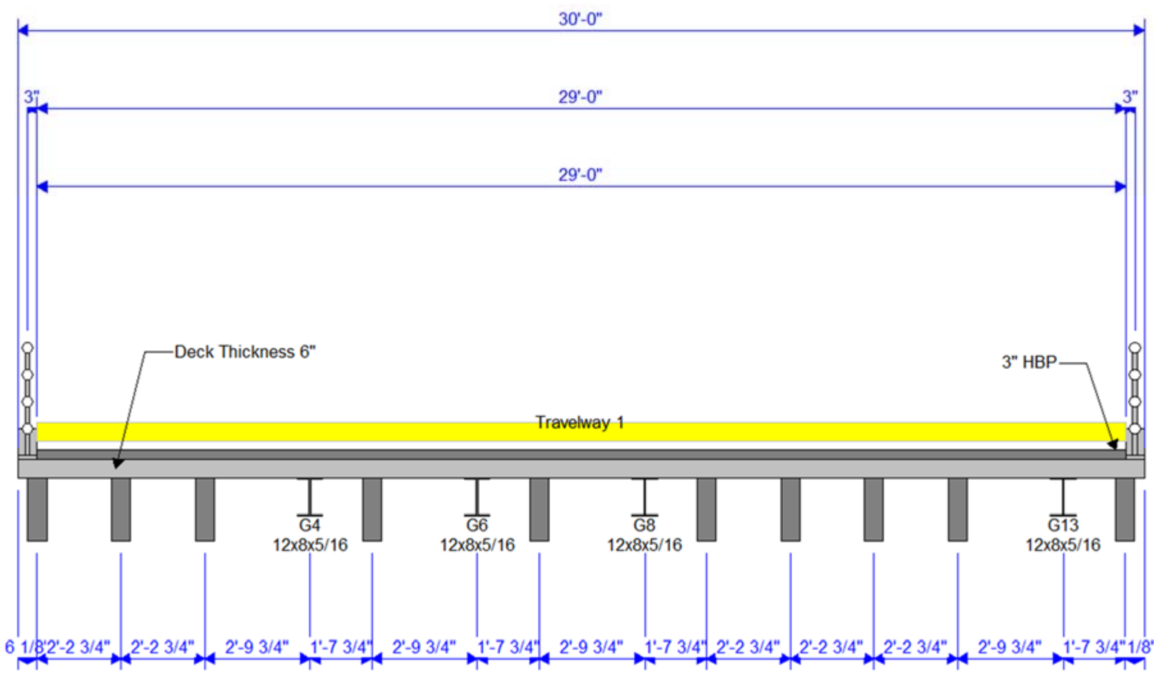
$S := 2.229167$ ft

Single lane: $LLDF_{SL} := \frac{S}{6.7} \cdot P_S$ $\quad LLDF_{SL} = 0.296$ (Wheels)

Multi lane: $LLDF_{ML} := \frac{S}{7.5} \cdot P_S$ $\quad LLDF_{ML} = 0.265$ (Wheels)

13.9 SISTER BEAM RATING EXAMPLE, STRUCTURE X-XX-X.

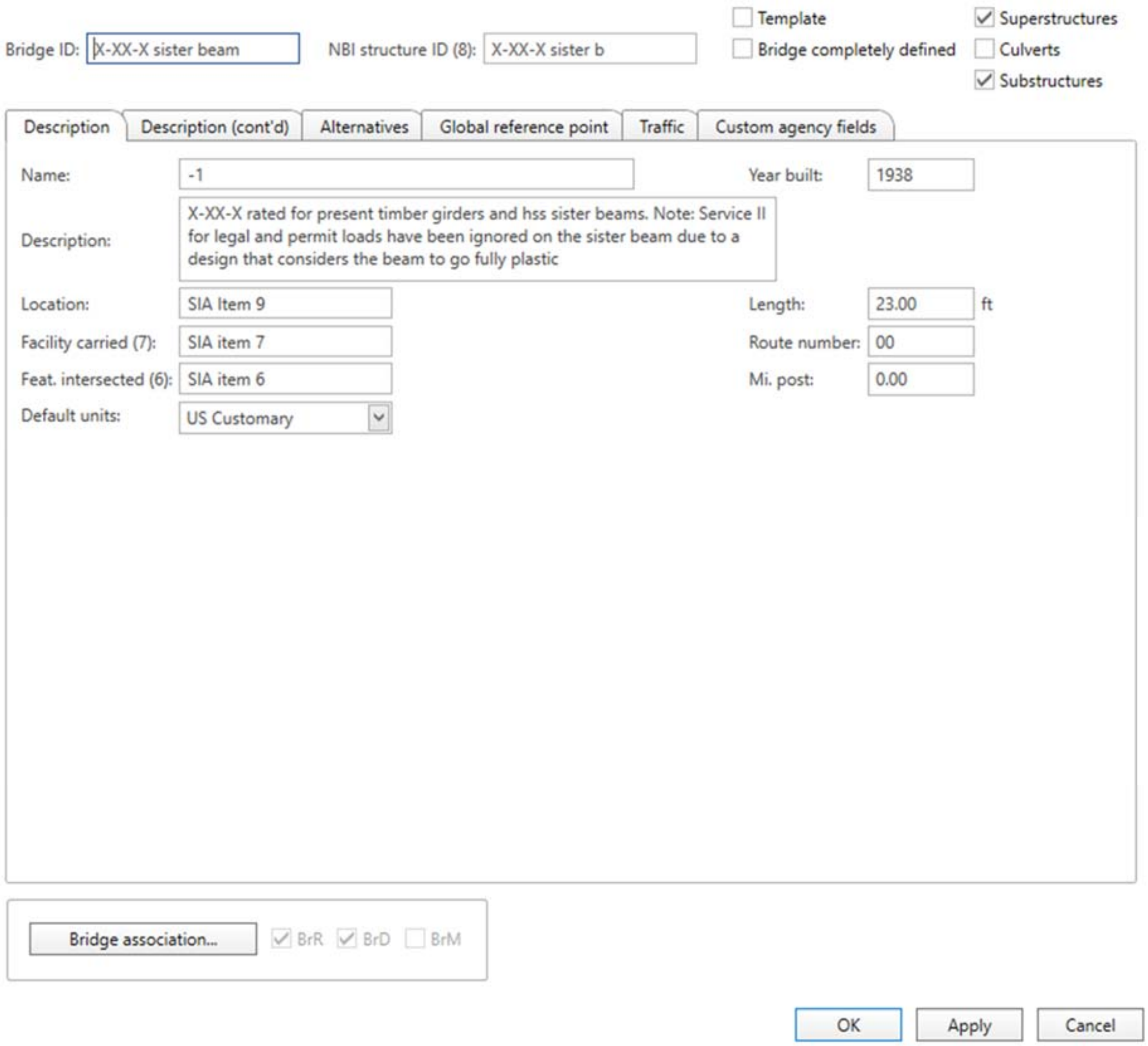
Structure X-XX-X AASHTOWare BrR Rating is presented below as an example. This structure is a 1-Span 23'-0" c-c timber stringer with steel sister beam for Girder number 4, 6, 8, and 13. The structure is 30'-0" out-to-out with original stringer spacing of 2'-2 ¾" c-c. The existing timber stringers are 6" wide x 20" deep Colorado Douglas Fir. The new Sister beam is 12x8x5/16 HSS steel section placed adjacent (side-by-side) the existing damaged or deteriorated stringer with spacing of 7" c-c. The damaged/deteriorated timber stringers are not modeled since it is assumed that the new sister-beam is carrying 100% of the load. Distribution factors should be calculated based on average girder spacing since the spacing can differ. The Live Load Impact shall be considered for the sister-beam, but not for the timber stringer. See Section 13.5 Example for more information



Structure X-XX-X Typical Section

AASHTOWARE BrR (VERSION 7.2) INPUT

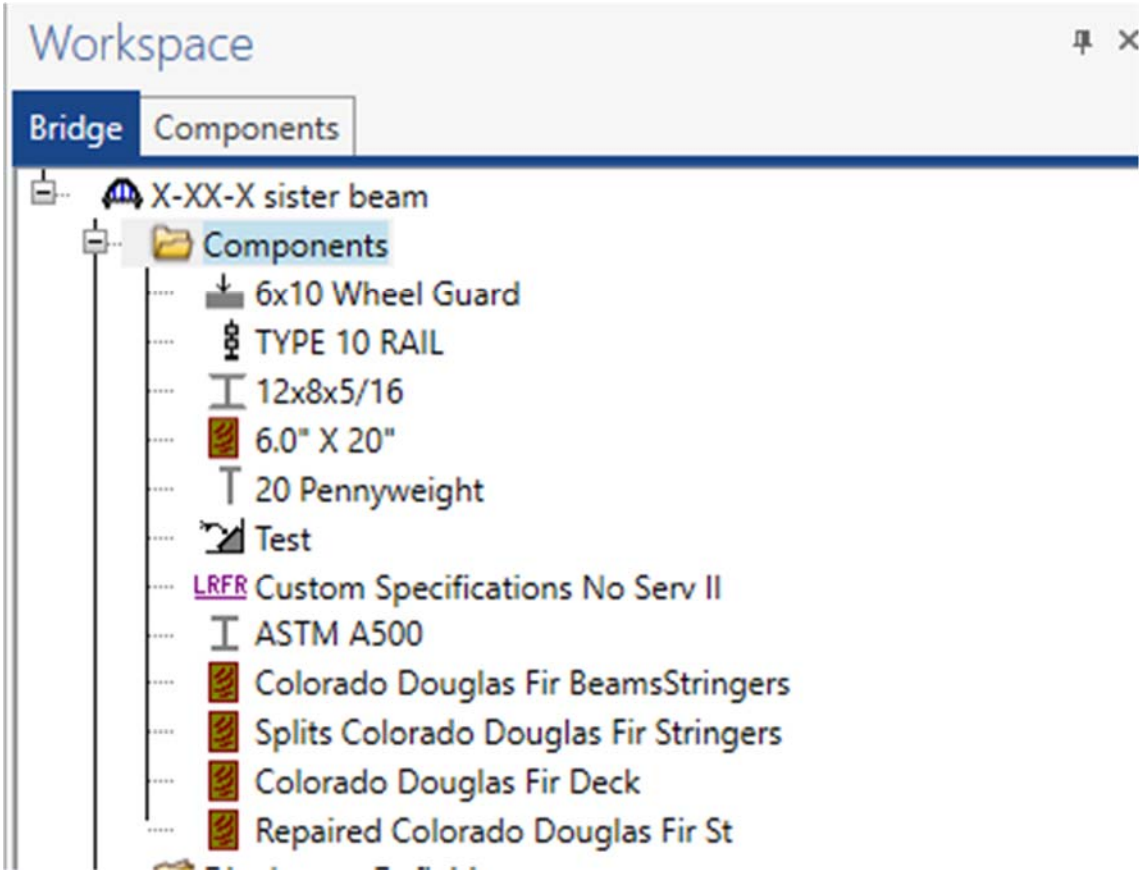
From the bridge explorer, create a new bridge and complete the bridge name and information tabulation.



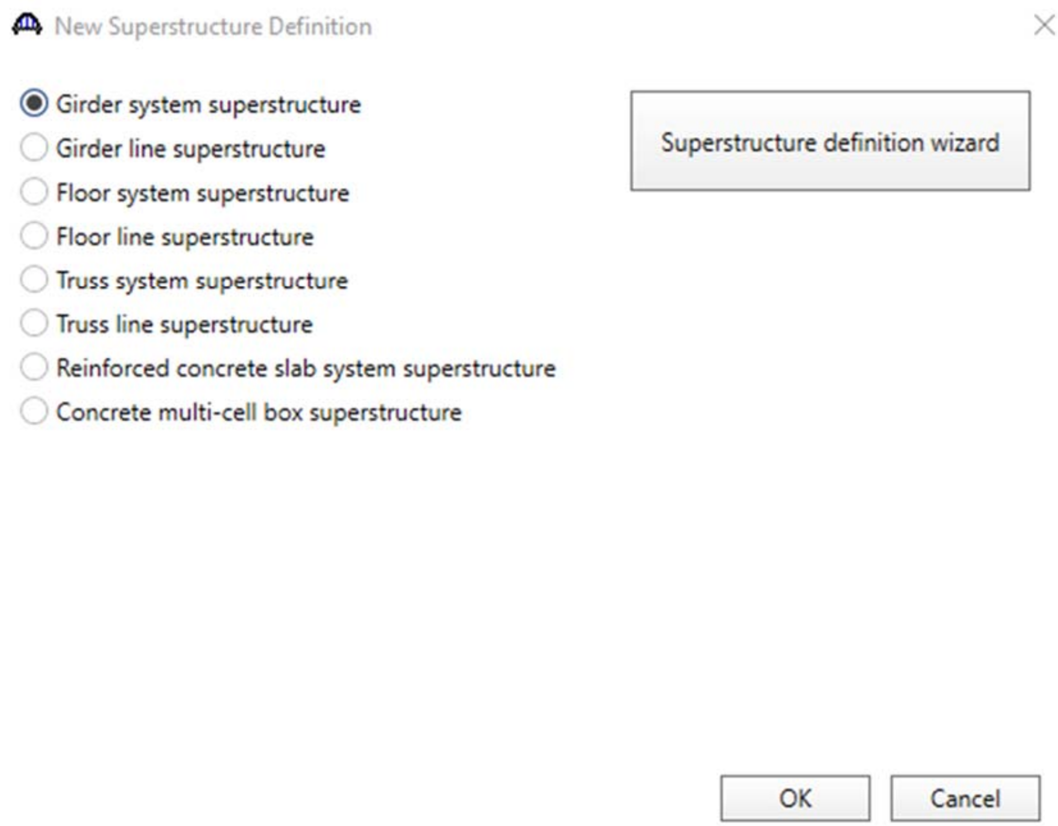
The Description should include CDOT/the Consultant company's name, the rater and checker initials, and date of completion.

The fields under the "Global reference point" and "Traffic" tabs should be completed matching the latest structure inspection and appraisal (SIA) report information.

The Components folder contains bridge components that are applicable to the entire bridge like appurtenances, beam shapes, specifications, and materials properties, see capture below:

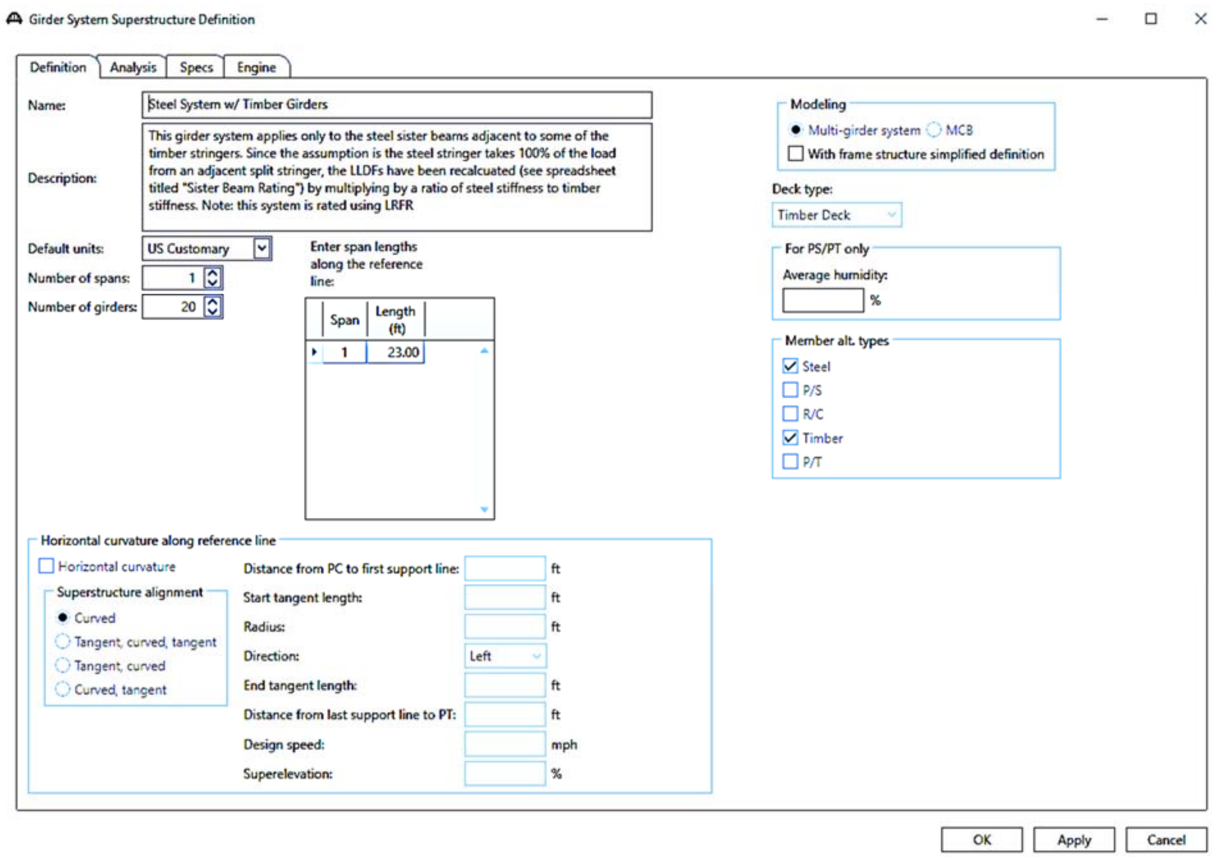


A Girder System superstructure is selected to create a new Superstructure Definition.

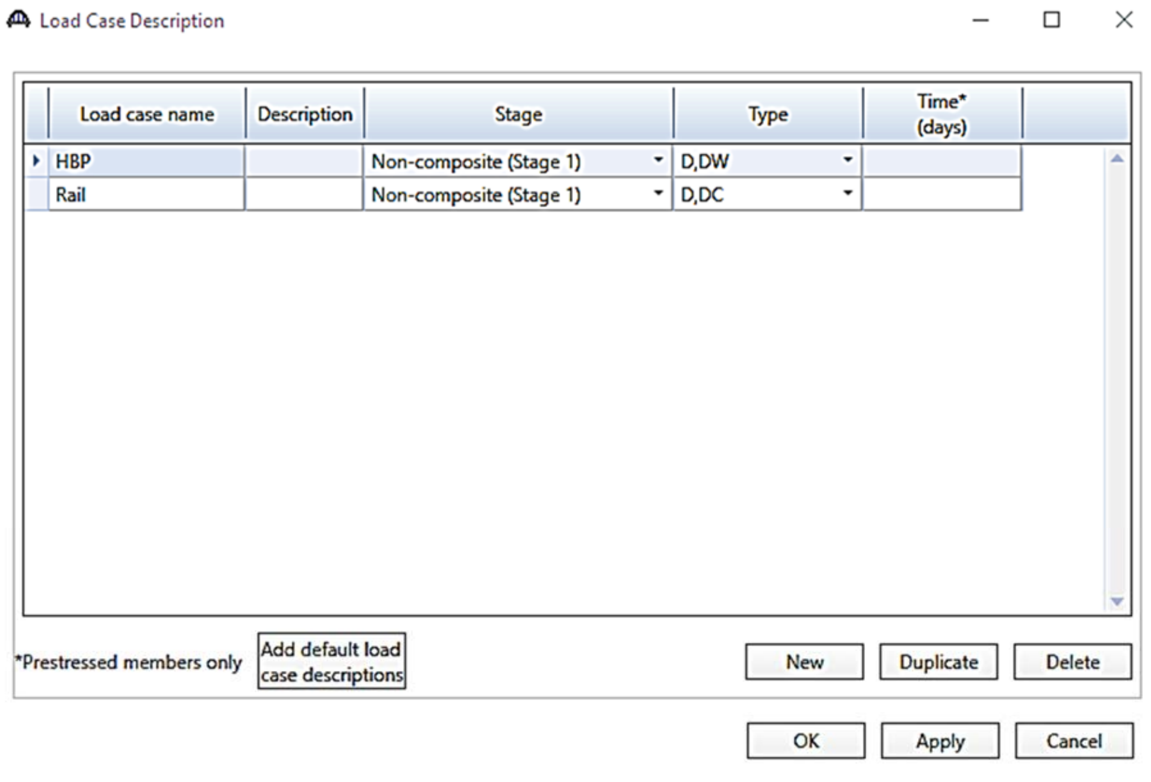


Complete the new Girder System Superstructure Definition information:

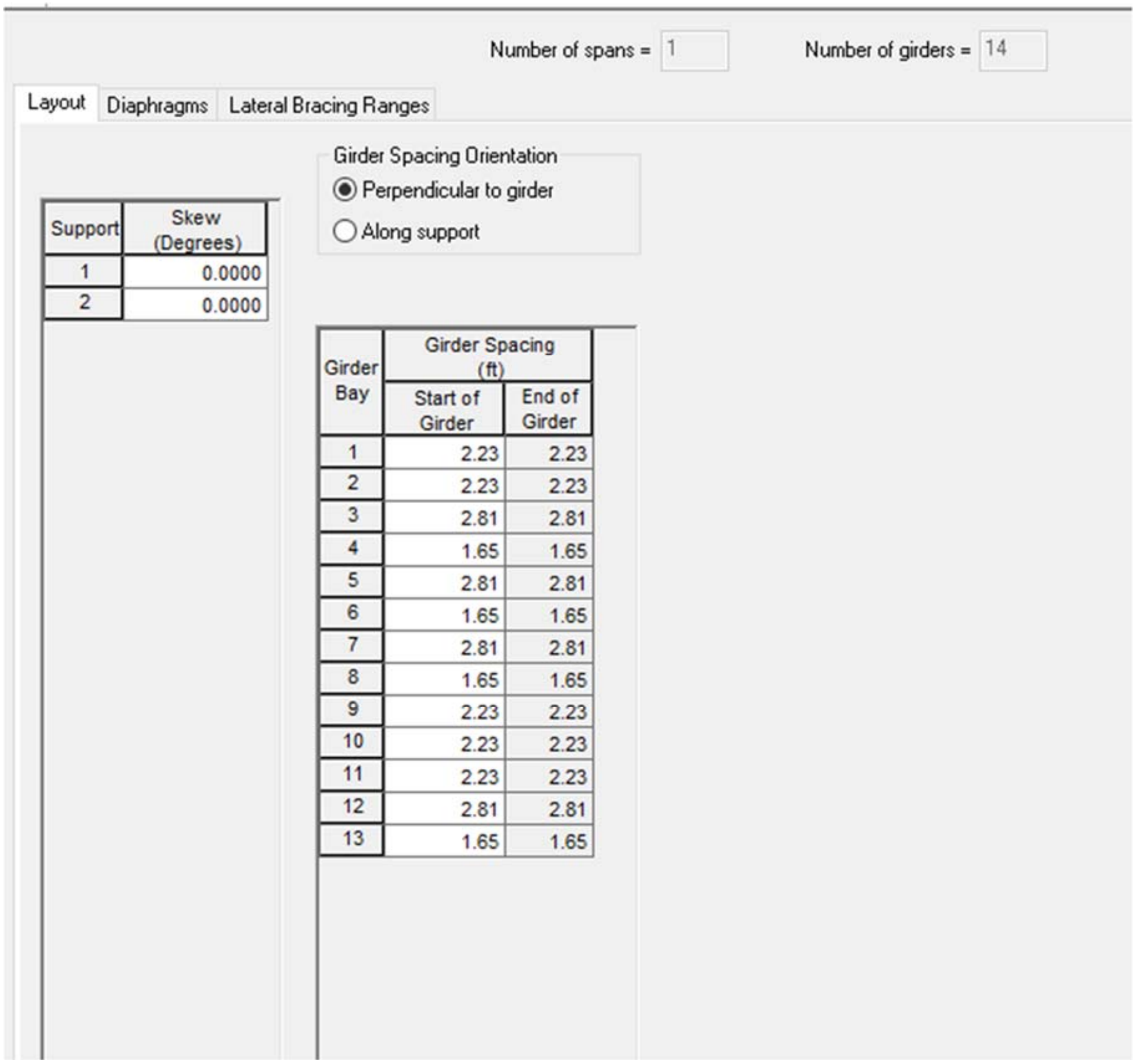
Two superstructure definitions should be created, one for the ASD Timber stringer rating, and the other for the LRFD Steel beam rating. The information below is shown for the steel beam rating only.



Complete the Load Case Description:



Complete Structure Framing Plan Details:



Number of spans = 1 Number of girders = 14

Layout Diaphragms Lateral Bracing Ranges

Girder Spacing Orientation

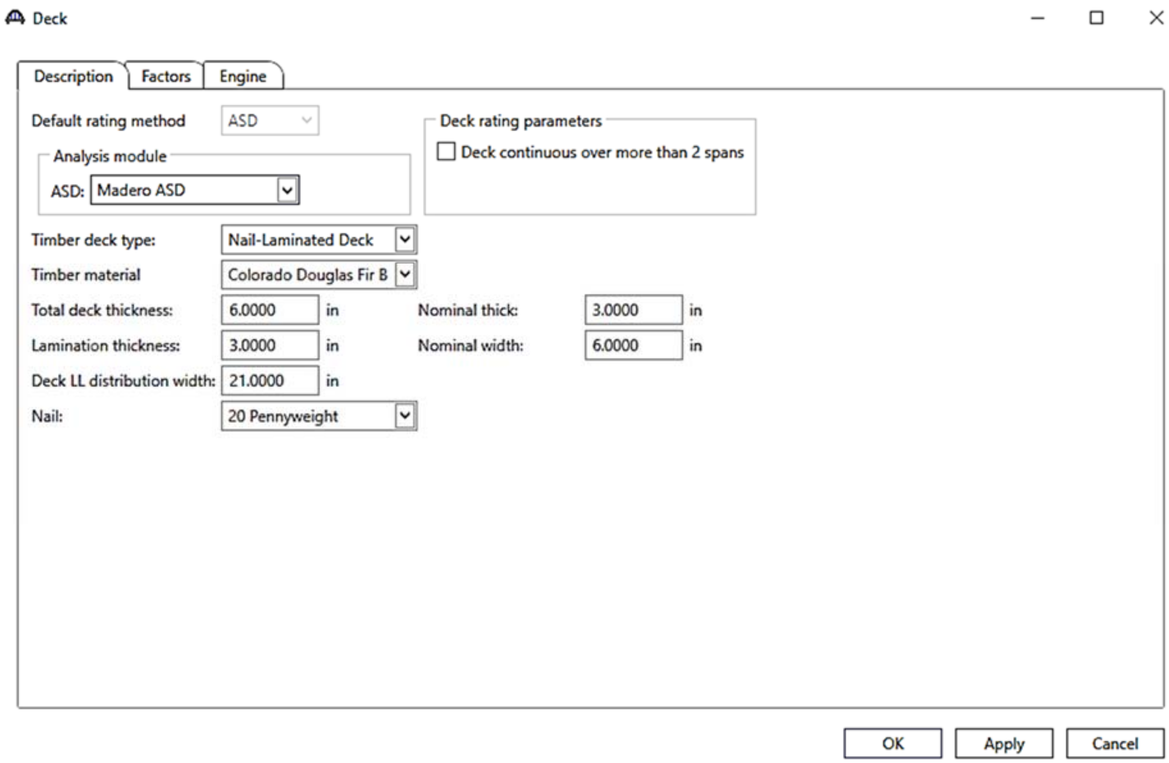
(•) Perpendicular to girder

( ) Along support

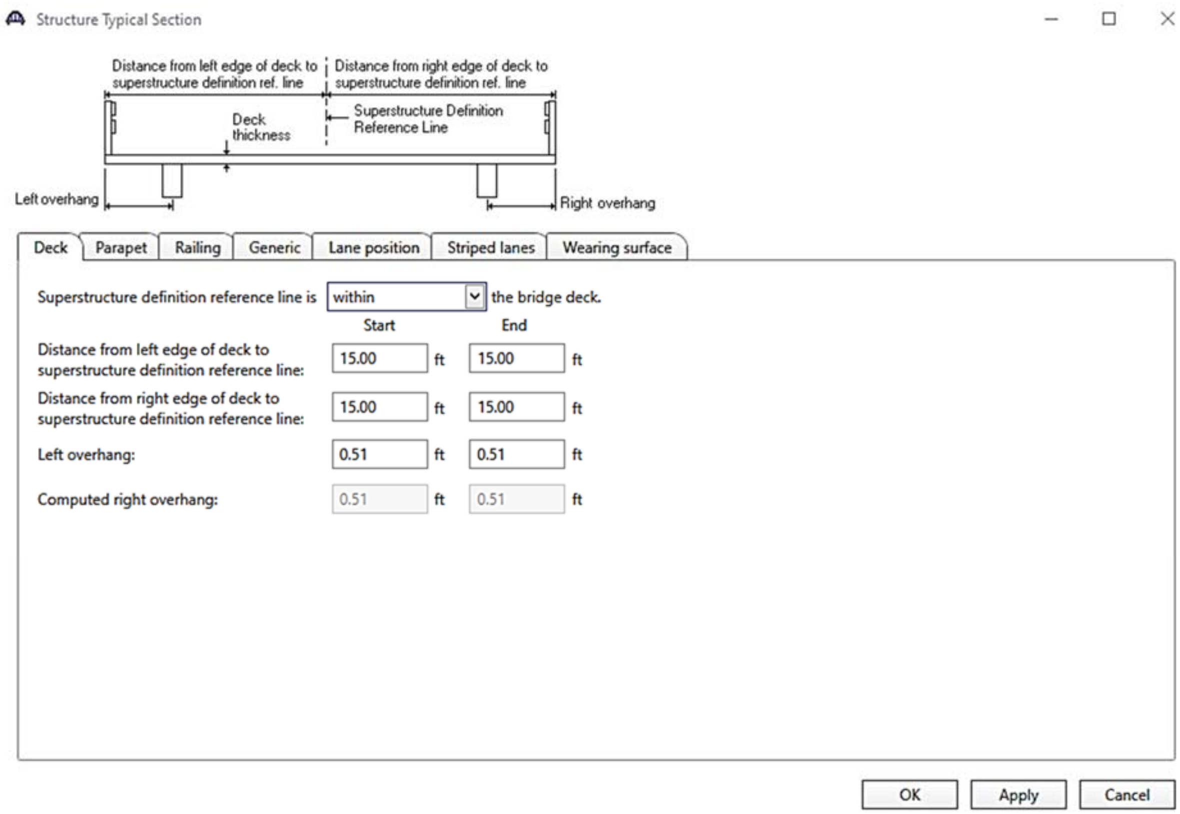
Support	Skew (Degrees)
1	0.0000
2	0.0000

Girder Bay	Girder Spacing (ft) Start of Girder	Girder Spacing (ft) End of Girder
1	2.23	2.23
2	2.23	2.23
3	2.81	2.81
4	1.65	1.65
5	2.81	2.81
6	1.65	1.65
7	2.81	2.81
8	1.65	1.65
9	2.23	2.23
10	2.23	2.23
11	2.23	2.23
12	2.81	2.81
13	1.65	1.65

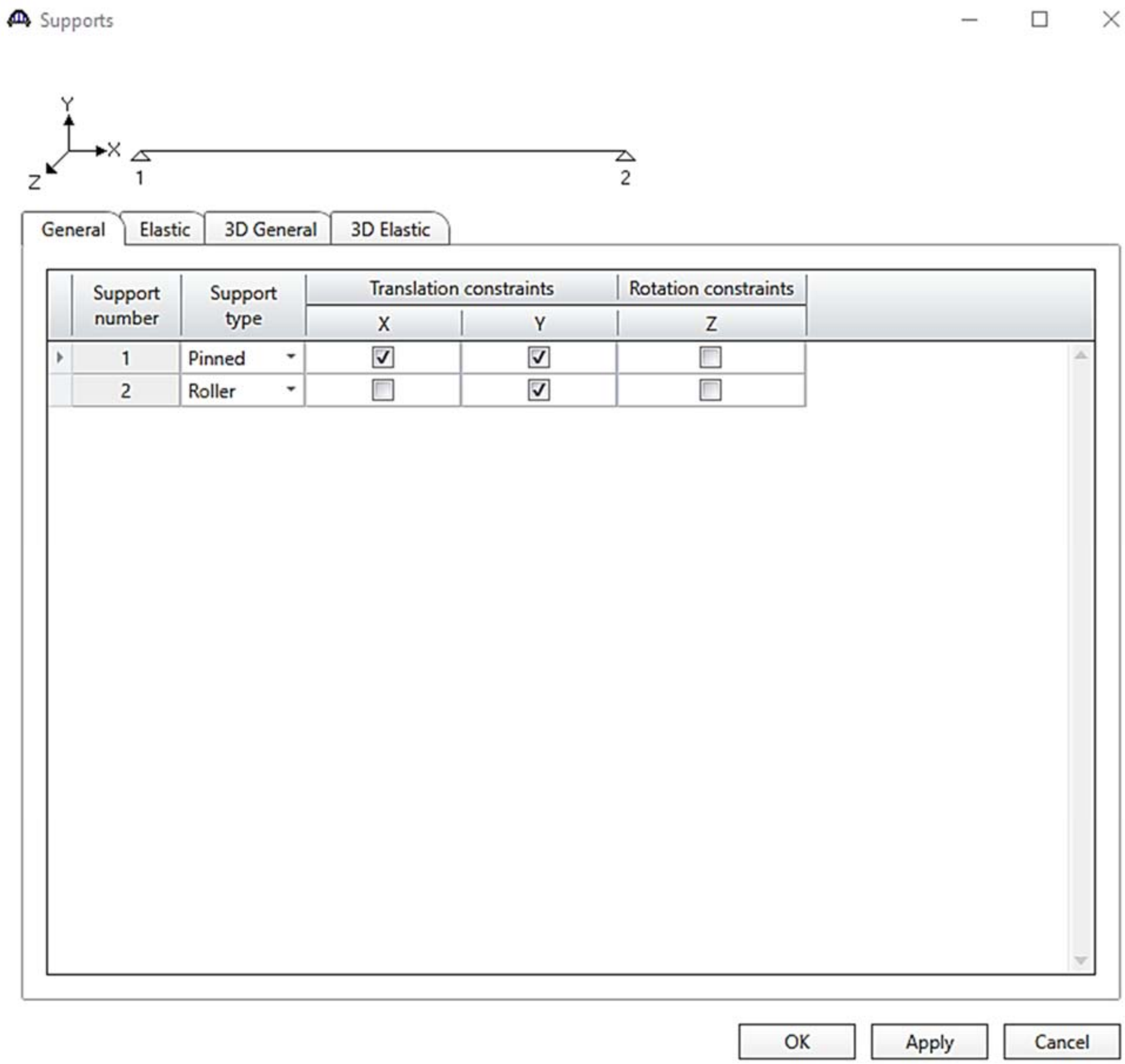
Complete the Deck folder information:



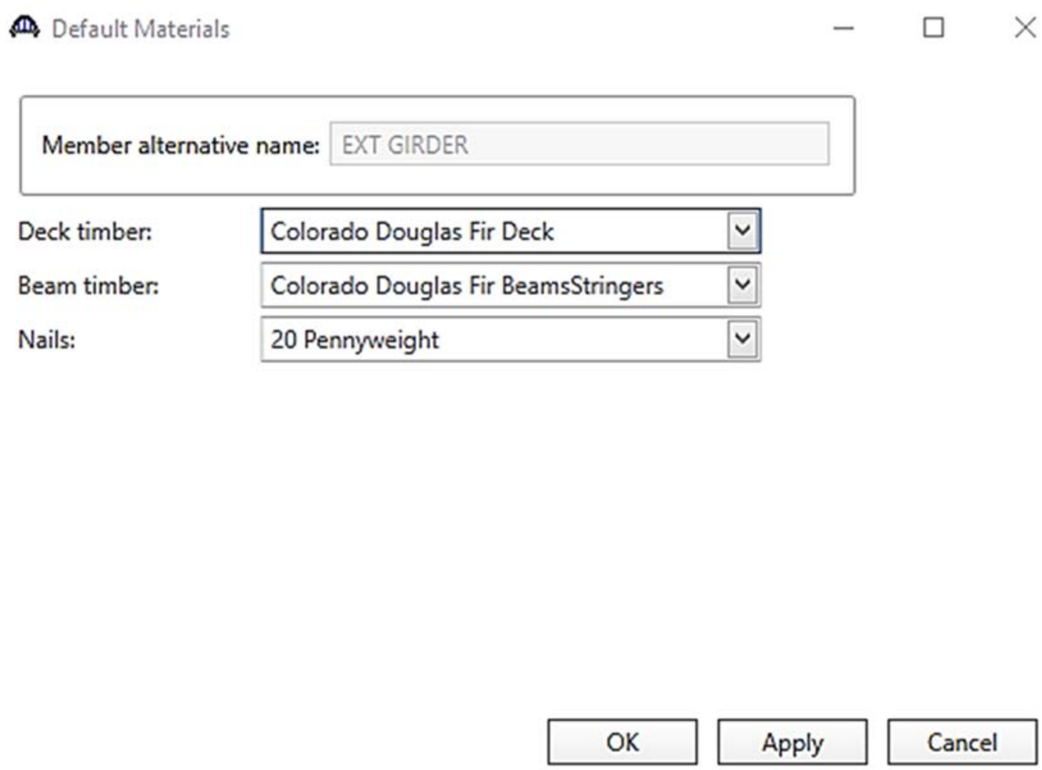
Complete Structure Typical Section information:



Complete each girder Supports information:

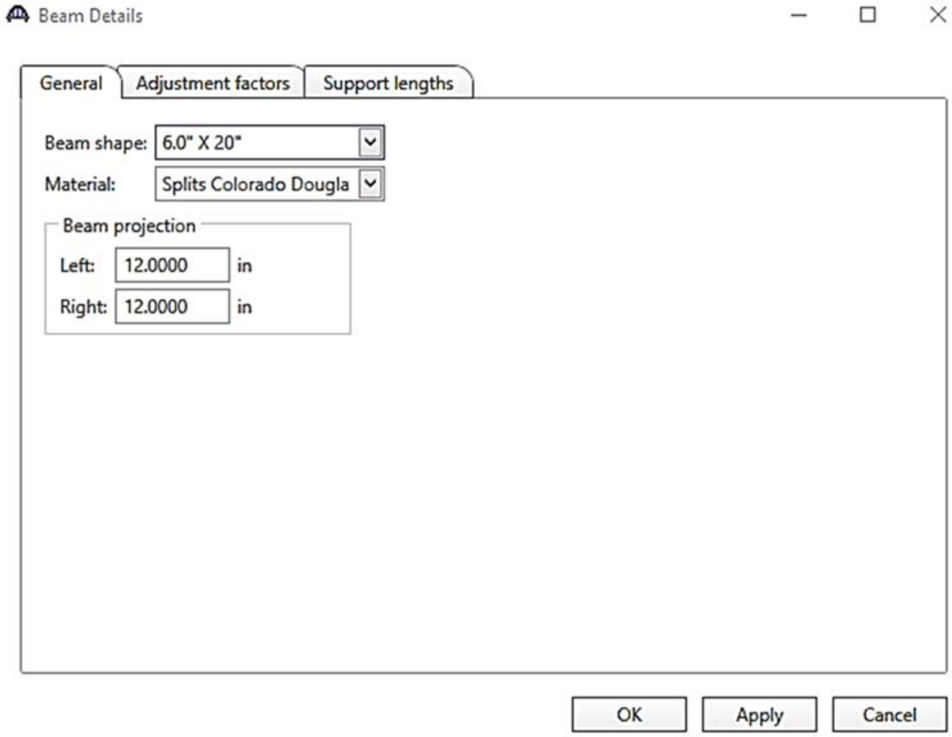


Complete Girders Default Material:

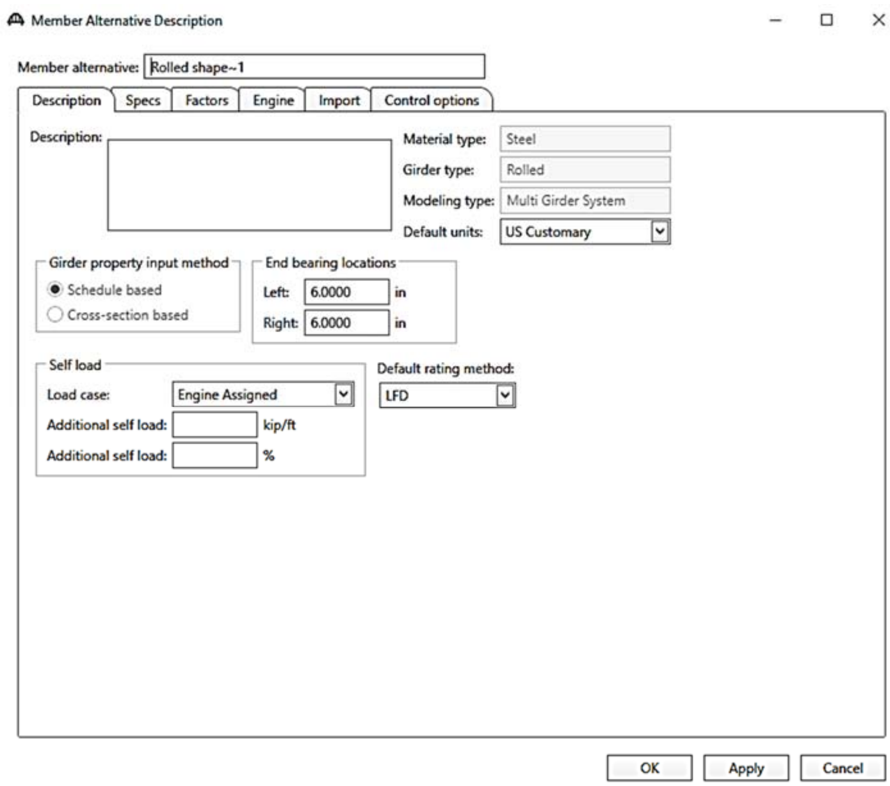


Complete the Beam Details information under each girder:

For Existing Timber Stringers:

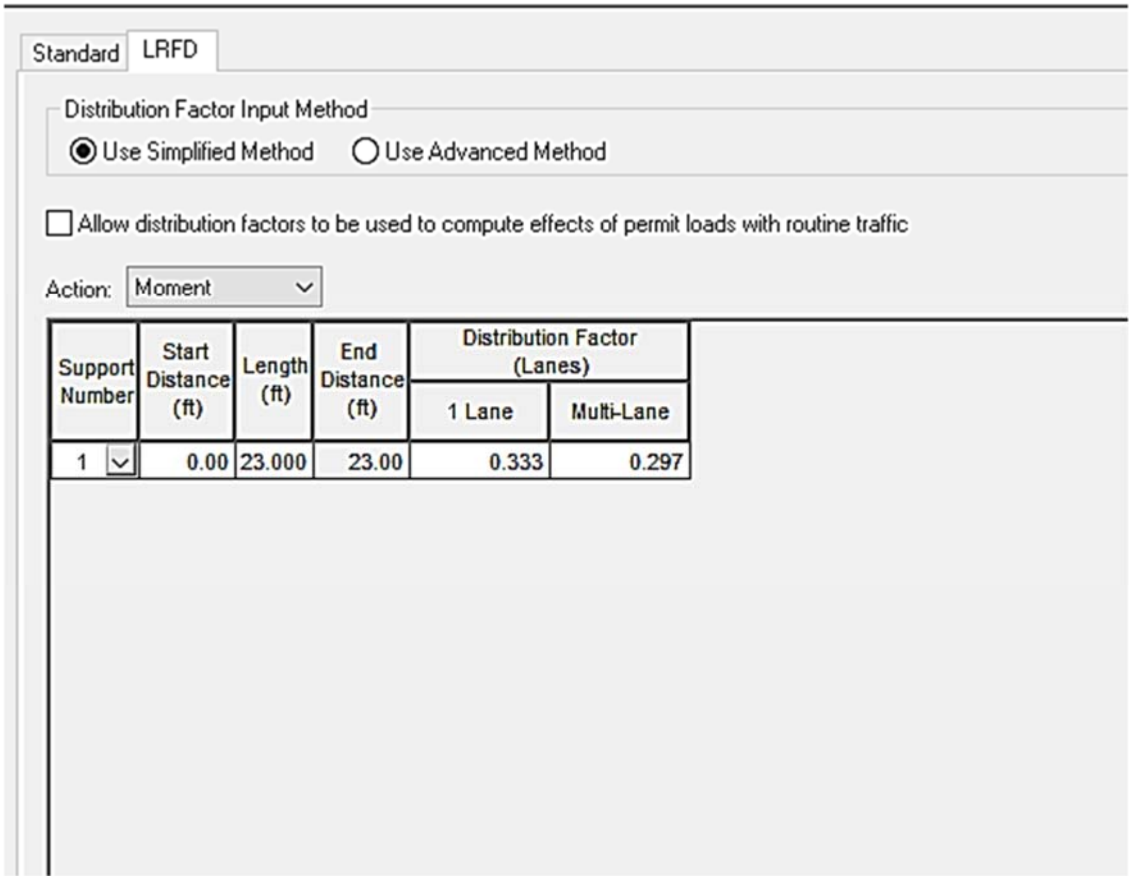


For New Steel Sister-Beams:



:

Complete the Live Load Distribution factors tabulation as per the design, hand calculation, or use the “Compute from typical section” button as appropriate.



Rating results are shown below for the existing sound timber stringers in ASD and the new sister-beam in LRFR.

COLORADO DEPARTMENT OF TRANSPORTATION

TIMBER RATING SUMMARY

Structure #	X-XX-X
State Highway #	
Batch I.D.	
Structure Type	TS
Parallel Structure #	

Rated using:
Asphalt thickness: 3 in.
☑ Colorado legal loads
☐ Interstate legal loads
☐ Multi-lane for Legal & Permit Vehicles
☑ Single lane for Legal & Permit Vehicles

Structural Member	Timber				
	Tons				
Inventory	34.56				
Operating	49.17				
Type 3 truck	42.04				
Type 3S2 truck	66.17				
Type 3-2 truck	66.17				
Type SU4 truck (27T)	41.71				
Type SU5 truck (31T)	44.63				
Type SU6 truck (35T)	44.83				
Type SU7 truck (39T)	52.22				
NRL (40T)	53.91				
EV2 (28.75T)	44.15				
EV3 (43T)	43.19				
Permit Truck (96T)	98.92				
Modified Tandem (50T)	61.51				

Comments:
Allowable Bending stress = 1600 psi
Allowable Split Shear Stress = 113 psi

Color Code: White

PE Seal

Rated by: (Print name and sign)	Date:	Checked by: (Print name and sign)	Date:

CDOT Staff Bridge - ASR 02/2019

COLORADO DEPARTMENT OF TRANSPORTATION
LOAD & RESISTANCE FACTOR RATING SUMMARY

Structure # X-XX-X
State Highway #
Batch I.D.
Structure Type TS w Steel Sister-B
Parallel Structure #

Rated using:
Asphalt thickness: 3 in.
☑ Colorado legal loads
☐ Interstate legal loads
☐ Multi-lane for Legal & Permit Vehicles
☑ Single lane for Legal & Permit Vehicles

Structural Member	Steel 12x8				
Rating Factor					
Inventory	32.79				
Operating	42.51				
Tons					
Type 3 truck	42.08				
Type 3S2 truck	66.23				
Type 3-2 truck	66.23				
Type SU4 truck (27T)	41.75				
Type SU5 truck (31T)	44.67				
Type SU6 truck (35T)	52.27				
Type SU7 truck (39T)	52.27				
NRL (40T)	53.96				
Lane-Type Legal						
EV2 (28.75T)	44.19				
EV3 (43T)	43.23				
Permit Truck (96T)	124.84				
Modified Tandem (50T)	78.60				

Type 3 Truck
Interstate 24 tons / Colorado 27 tons
42.1 tons

Type 3S2 Truck
Interstate 38 tons / Colorado 42.5 tons
66.2 tons

Type 3-2 Truck
Interstate 39 tons / Colorado 42.5 tons
66.2 tons

Comments:
Steel Sister Beam is HSS - 12x8x5/16.

Color Code: White

PE Seal

Rated by: (Print name and sign)	Date:	Checked by: (Print name and sign)	Date:

CDOT Staff Bridge - LRFR 02/2019